This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

The Earth and Man

C

18827 d 12

THE EARTH

AS

MODIFIED BY HUMAN ACTION.

A NEW EDITION OF MAN AND NATURE.

BY

GEORGE P. MARSH.

"Not all the winds, and storms, and earthquakes, and seas, and seasons of the world, have done so much to revolutionise the earth as MAN, the power of an endless life, has done since the day he came forth upon it, and received dominion over it."—H. BUSHNELL, *Sermon on the Power of an Endless Life.*

LONDON:
SAMPSON LOW, MARSTON, LOW, AND SEARLE,
CROWN BUILDINGS, 188 FLEET ST.
NEW YORK:
SCRIBNER, ARMSTRONG & COMPANY.
1874.

PREFACE TO THE FIRST EDITION.

THE object of the present volume is: to indicate the character and, approximately, the extent of the changes produced by human action in the physical conditions of the globe we inhabit; to point out the dangers of imprudence and the necessity of caution in all operations which, on a large scale, interfere with the spontaneous arrangements of the organic or the inorganic world; to suggest the possibility and the importance of the restoration of disturbed harmonies and the material improvement of waste and exhausted regions; and, incidentally, to illustrate the doctrine that man is, in both kind and degree, a power of a higher order than any of the other forms of animated life, which, like him, are nourished at the table of bounteous nature.

In the rudest stages of life, man depends upon spontaneous animal and vegetable growth for food and clothing, and his consumption of such products consequently diminishes the numerical abundance of the species which serve his uses. At more advanced periods, he protects and propagates certain es culent vegetables and certain fowls and quadrupeds, and, at the same time, wars upon rival organisms which prey upon these objects of his care or obstruct the increase of their numbers. Hence the action of man upon the organic world tends to derange its original balances, and while it reduces the numbers of some species, or even extirpates them altogether, it multiplies other forms of animal and vegetable life.

The extension of agricultural and pastoral industry involves an enlargement of the sphere of man's domain, by encroachment upon the forests which once covered the greater part of the earth's surface otherwise adapted to his occupation. The felling of the woods has been attended with momentous consequences to the drainage of the soil, to the external configuration of its surface, and probably, also, to local climate; and the importance of human life as a transforming power is, perhaps, more clearly demonstrable in the influence man has thus exerted upon superficial geography than in any other result of his material effort.

Lands won from the woods must be both drained and irrigated; river-banks and maritime coasts must be secured by means of artificial bulwarks against inundation by inland and by ocean floods; and the needs of commerce require the improvement of natural and the construction of artificial channels of navigation. Thus man is compelled to extend over the unstable waters the empire he had already founded upon the solid land.

The upheaval of the bed of seas and the movements of water and of wind expose vast deposits of sand, which occupy space required for the convenience of man, and often, by the drifting of their particles, overwhelm the fields of human industry with invasions as disastrous as the incursions of the ocean. On the other hand, on many coasts, sand-hills both protect the shores from erosion by the waves and currents, and shelter valuable grounds from blasting sea-winds. Man, therefore, must sometimes resist, sometimes promote, the formation and growth of dunes, and subject the barren and flying sands to the same obedience to his will to which he has reduced other forms of terrestrial surface.

Besides these old and comparatively familiar methods of material improvement, modern ambition aspires to yet grander achievements in the conquest of physical nature, and projects are meditated which quite eclipse the boldest enterprises hitherto undertaken for the modification of geographical surface.

The natural character of the various fields where human industry has effected revolutions so important, and where the multiplying population and the impoverished resources of the globe demand new triumphs of mind over matter, suggests a corresponding division of the general subject, and I have conformed the distribution of the several topics to the chronological succession in which man must be supposed to have extended his sway over the different provinces of his material kingdom. I have, then, in the introductory chapter, stated, in a comprehensive way, the general effects and the prospective consequences of human action upon the earth's surface and the life which peoples it. This chapter is followed by four others in which I have traced the history of man's industry as exerted upon Animal and Vegetable Life, upon the Woods, upon the Waters, and upon the Sands; and to these I have added a concluding chapter upon Man.

It is perhaps superfluous to add, what indeed sufficiently appears upon every page of the volume, that I address myself not to professed physicists, but to the general intelligence of observing and thinking men; and that my purpose is rather to make practical suggestions than to indulge in theoretical speculations more properly suited to a different class from that for which I write.

GEORGE P. MARSH.

December 1, 1863.

PREFACE TO THE PRESENT EDITION.

In preparing for the press an Italian translation of this work, published at Florence in 1870, I made numerous corrections in the statement of both facts and opinions; I incorporated into the text and introduced in notes a large amount of new data and other illustrative matter; I attempted to improve the method by differently arranging many of the minor subdivisions of the chapters; and I suppressed a few passages which seemed to me superfluous.

In the present edition, which is based on the Italian translation, I have made many further corrections and changes of arrangement of the original matter; I have rewritten a considerable portion of the work, and have made, in the text and in notes, numerous and important additions, founded partly on observations of my own, partly on those of other students of Physical Geography, and though my general conclusions remain substantially the same as those I first announced, yet I think I may claim to have given greater completeness and a more consequent and logical form to the whole argument.

Since the publication of the original edition, Mr. Elisée Reclus, in the second volume of his admirable work, *La Terre* (Paris, 1868), lately made accessible to English-reading students, has treated, in a general way, the subject I have undertaken to discuss. He has, however, occupied himself with the conservative and restorative, rather than with the destructive, effects of human industry, and he has drawn an attractive and encouraging picture of the ameliorating influences of the action of man, and of the compensations by which he, consciously or unconsciously, makes amends for the deterioration which he has produced in the medium he inhabits. The labors of Mr. Reclus, therefore, though aiming at a much higher and wider scope than I have had in view, are, in this particular point, a complement to my own. I earnestly recommend the work of this able writer to the attention of my readers.

GEORGE P. MARSH.

ROME, *May* 1, 1873.

BIBLIOGRAPHICAL LIST

OF WORKS CONSULTED IN THE PREPARATION OF THIS VOLUME.

Amersfoordt, J. P. Het Haarlemmermeer, Oorsprong, Geschiedenis, Droogmaking. Haarlem, 1857. 8vo.

Andresen, C. C. Om Klitformationen og Klittens Behandling og Bestyrelse. Kjöbenhavn, 1861. 8vo.

Annali di Agricoltura, Industria e Commercio. Pubblicati per cura del Ministero d'Agricoltura, Industria e Commercio. Fasc i–v. Torino, 1862–'3. 8vo.

Arago, F. Extracts from, in Becquerel, Des Climats.

Arriani, Opera. Lipsiæ, 1856. 2 vols. 12mo.

Asbjörnsen, P. Chr. Om Skovene og om et ordnet Skovbrug i Norge. Christiania, 1855. 12mo.

Aus der Natur. Die neuesten Entdeckungen auf dem Gebiete der Naturwissenschaften. Leipzig, various years. 20 vols. 8vo.

Avé-Lallemant, K. C. B. Die Benutzung der Palmen am Amazonenstrom in der Oekonomie der Indier. Hamburg, 1861. 18mo.

Babinet. Études et Lectures sur les Sciences d'Observation. Paris, 1855–1863. 7 vols. 18mo.

Baer, von. Kaspische Studien. St. Petersburg, 1855–1859. 8vo.

Barth, Heinrich. Wanderungen durch die Küstenländer des Mittelmeeres. V. i. Berlin, 1849. 8vo.

Barth, J. B. Om Skovene i deres Forhold til Nationalœconomien. Christiania, 1857. 8vo.

Baude, J. J. Les Côtes de la Manche, Revue des Deux Mondes, 15 Janvier, 1859.

Baumgarten. Notice sur les Rivières de la Lombardie; in Annales des Ponts et Chaussées, 1847, 1er sémestre, pp. 129–199.

Beckwith, Lieut. Report in Pacific Railroad Report, vol. ii.

Becquerel. Des Climats et de l'Influence qu'exercent les Sols boisés et non-boisés. Paris, 1853. 8vo.

——— Éléments de Physique Terrestre et de Météorologie. Paris, 1847. 8vo.

Belgrand. De l'Influence des Forêts sur l'écoulement des Eaux Pluviales; in Annales des Ponts et Chaussées, 1854, 1er sémestre, pp. 1, 27.

Berg, Edmund von. Das Verdrängen der Laubwälder im Nördlichen Deutschlande durch die Fichte und die Kiefer. Darmstadt, 1844. 8vo.

Bergsöe, A. F. Greve Ch. Ditlev Frederik Reventlovs Virksomhed som Kongens Embedsmand og Statens Borger. Kjöbenhavn, 1837. 2 vols. 8vo.

Berlepsch, H. Die Alpen in Natur-und Lebensbildern. Leipzig, 1862. 8vo.

Bianchi, Celestino. Compendio di Geografia Fisica Speciale d'Italia. Appendice alla traduzione Italiana della Geog.-Fisica di Maria Somerville. Firenze, 1861. (2d vol. of translation.)

Bigelow, John. Les États Unis d'Amérique en 1863. Paris, 1863. 8vo.

Blake, Wm. P. Reports in Pacific Railroad Report, vols. ii and v.

Blanqui. Mémoire sur les Populations des Hautes Alpes; in Mémoires de l'Académie des Sciences Morales et Politiques, 1843.

——— Voyage en Bulgarie. Paris, 1843. 12mo.

——— Précis Élémentaire d'Économie Politique, suivi du Résumé de l'Histoire du Commerce et de l'Industrie. Paris, 1857. 12mo.

Boitel, Amédée. Mise en valeur des Terres pauvres par le Pin Maritime. 2d edition. Paris, 1857. 8vo.

Bonnemère, Eugène. Histoire des Paysans depuis la fin du Moyen Age jusqu'à nos jours. Paris, 1856. 2 vols. 8vo.

Böttger, C. Das Mittelmeer. Leipzig, 1859.

Boussingault, J. B. Économie Rurale considerée dans ses Rapports avec la Chimie, la Physique, et la Météorologie. 2d edition. Paris, 1851. 2 vols. 8vo.

Brémontier, N. T. Mémoire sur les Dunes; in Annales des Ponts et Chaussées, 1833, 1er sémestre, pp. 145, 223.

Brincken, J. von den. Ansichten über die Bewaldung der Steppen des Europæischen Russland. Braunschweig, 1854. 4to.

Büttner, J. G. Zur Physikalischen Geographie; in Berghaus, Geographisches Jahrbuch, No. iv, 1852, pp. 9–19.

Caimi, Pietro. Cenni sulla Importanza e Coltura dei Boschi. Milano, 1857. 8vo.

Cantegril, and others. Extracts in Comptes Rendus à l'Académie des Sciences. Paris, 1861.

Castellani. Dell' immediata influenza delle Selve sul corso delle acque. Torino, 1818, 1819. 2 vols. 4to.

Census of the United States for 1860. Preliminary Report on, Washington, 1862. 8vo.

Cerini, Giuseppe. Dell' Impianto e Conservazione dei Boschi. Milano, 1844. 8vo.

Champion, Maurice. Les Inondations en France depuis le VIme Siècle jusqu'à nos jours. Paris, 1858, 1862. Vols. i–iv, 8vo.

Chateauvieux, F. Lullin de. Lettres sur l'Italie. Seconde edition, Genève, 1834. 8vo.

Chevandier. Extracts in Comptes Rendus à l'Académie des Sciences. Juillet-Decembre, 1844. Paris.

Clavé, Jules. Études sur l'Économie Forestière. Paris, 1862. 12mo.

——— La Forêt de Fontainebleau ; Revue des Deux Mondes, 1 Mai, 1863.

Cooper, J. G. The Forests and Trees of Northern America ; in Report of the Commissioner of Patents for the year 1860, pp. 416–445.

Cotta, Bernhard. Deutschlands Boden. Leipzig, 1858. 2 vols. 8vo.

——— Vorwort zu Paramelle's Quellenkunde. See *Paramelle.*

——— Die Alpen. Leipzig, 1851. 8vo.

Coultas, Harland. What may be Learned from a Tree. New York, 1860. 8vo.

Courier, Paul-Louis. Œuvres Complètes. Bruxelles, 1833. 8vo.

Dana, James D. Manual of Geology. Philadelphia, 1863. 8vo.

Delamarre, L. G. Historique de la Création d'une Richesse Millionaire par la culture des Pins. Paris, 1827. 8vo.

D'Héricourt, A. F. Les Inondations et le livre de M. Vallès ; Annales Forestières, December, 1857, pp. 310, 321. Paris.

Diggelen, B. P. G. van. Groote Werken in Nederland. Zwolle, 1855. 8vo.

Dumas, M. J. La Science des Fontaines. 2me edition, Paris, 1857. 8vo.

Dumont, Aristide. Des Travaux Publics dans leurs Rapports avec l'Agriculture. Paris, 1847. 8vo.

Dwight, Timothy. Travels in New England and New York. New Haven, 1821. 4 vols. 8vo.

Emerson, George B. A Report on the Trees and Shrubs growing naturally in Massachusetts. Boston, 1850. 8vo.

Emory, Wm. H., Col. Report of Commissioners of the United States and Mexican Boundary Survey, vol. i, 1857.

Escourrou-Miliago, A. L'Italie à propos de l'Exposition Universelle de Paris. Paris, 1856. 8vo.

Evelyn, John. Silva ; or, a Discourse of Forest Trees. With Notes by A. Hunter. York, 1786. 2 vols. 4to.

——— Terra, a Philosophical Discourse of Earth. York, 1786. 4to. in vol. ii of Silva.

Féraud-Giraud, L. J. D. Police des Bois, Défrichements et Reboisements

Commentaire pratique sur les lois promulguées en 1859 et 1860. Paris, 1861. 8vo.

Ferrara, Francesco. Descrizione dell' Etna. Palermo, 1818. 8vo.

Feuillide, C. de. L'Algérie Française. Paris, 1856. 8vo.

Figuier, Louis. L'Année Scientifique et Industrielle. Paris, 1862–'3. 12mo.

Finnboga Saga hins rama. Kaupmannahöfn, 1812. 4to.

Foissac, P. Meteorologie mit Rücksicht auf die Lehre vom Kosmos, Deutsch von A. H. Emsmann. Leipzig, 1859. 8vo.

Forchhammer, G. Geognostische Studien am Meeres-Ufer; in Leonhard und Bronn's Neues Jahrbuch für Mineralogie, Geognosie, Geologie, etc. Jahrgang, 1841, pp. 1–38.

Fossombroni, Vittorio. Memorie Idraulico-Storiche sopra la Val-di-Chiana. Montepulciano, 3za edizione, 1835. 8vo.

Fraas, C. Klima und Pflanzenwelt in der Zeit. Landshut, 1847. 8vo.

Frisi, Paolo. Del Modo di regolare i Fiumi e i Torrenti. Lucca, 1762. 4to.

Fuller, Thomas. The History of the Worthies of England. London, 1662. Folio.

Gilliss, J. M., Capt. United States Naval Astronomical Expedition to the Southern Hemisphere. Washington, 1855. 2 vols. 4to.

Giorgini. Paper by; in Salvagnoli-Marchetti, Rapporto sul Bonificamento delle Maremme, App. v.

Girard et Parent-Duchatelet. Rapport sur les Puits forés dits Artésiens; Annales des Ponts et Chaussées, 1833, 2me sémestre, 313–344.

Graham, J. D., Lieut.-Col. A Lunar Tidal Wave in the North American Lakes demonstrated. Cambridge, 1861. 8vo. *pamphlet.* Also in vol. xiv, Proc. Am. Ass. for Adv. of Science for 1860.

Hakluyt, Richard. The Principal Navigations, Voyages, &c., of the English Nation. London, 1598–'9. 3 vols. folio.

Harrison, W. An Historicall Description of the Iland of Britaine; in Holinshed's Chronicles. Reprint of 1807, vol. i.

Hartwig, G. Das Leben des Meeres. Frankfurt, 1857. 8vo.

Haxthausen, August von. Transkaukasia. Leipzig, 1856. 2 vols. 8vo.

Henry, Prof. Joseph. Paper on Meteorology in its connection with Agriculture; in United States Patent Office Report for 1857, pp. 419–550.

Herschel, Sir J. F. W. Physical Geography. Edinburgh, 1861. 12mo.

Heyer, Gustav. Das Verhalten der Waldbäume gegen Licht und Schatten. Erlangen, 1852. 8vo.

Hohenstein, Adolph. Der Wald sammt dessen wichtigem Einfluss auf das Klima, &c. Wien, 1860. 8vo.

Humboldt, Alexander von. Ansichten der Natur. Dritte Ausgabe, Stuttgart und Tübingen, 1849. 2 vols. 12mo.

Hummel, Karl. Physische Geographie. Graz, 1855. 8vo.

Hunter, A. Notes to Evelyn, Silva, and Terra. York, 1786. See *Evelyn.*

Jacini, Stefano. La Proprietà Fondiaria e le Popolazioni agricole in Lombardia. Milano e Verona, 1857. 8vo.

Joinville. Histoire de Saint-Louis. Nouvelle Collection des Mémoires pour servir à l'Histoire de France, par Michaud et Poujoulat. Tome i. Paris, 1836. 8vo.

Josselyn, John. New England Rarities. London, 1672. 12mo.

Knorr, E. A. Studien über die Buchen-Wirthschaft. Nordhausen, 1863. 8vo.

Kohl, J. G. Alpenreisen. Dresden und Leipzig, 1849. 3 vols. 8vo.

——— Die Marschen und Inseln der Herzogthümer Schleswig und Holstein. Dresden und Leipzig, 1846. 3 vols. 8vo.

Kramer, Gustav. Der Fuciner-See. Berlin, 1839. 4to.

Krause, G. C. A. Der Dünenbau auf den Ostsee-Küsten West-Preussens. 1850. 8vo.

Kremer, Alfred von. Ægypten, Forschungen über Land und Volk. Leipzig, 1863. 2 vols. 8vo.

Kriegk, G. L. Schriften zur allgemeinen Erdkunde. Leipzig, 1840. 8vo.

Ladoucette, J. C. F. Histoire, Topographie, Antiquités, Usages, Dialectes des Hautes Alpes. Seconde édition, 1834. 1 vol. 8vo. and Atlas.

Læstadius, Lars Levi. Om Möjligheten och Fördelen af allmänna Uppodlingar i Lappmarken. Stockholm, 1824. 12mo.

Læstadius, Petrus. Journal för första året af hans Tjenstgöring såsom Missionaire i Lappmarken. Stockholm, 1831. 8vo.

——— Fortsättning af Journalen öfver Missions-Resor i Lappmarken. Stockholm, 1833. 8vo.

Lampridius. Vita Elagabali in Script. Hist., August.

Landgrebe, Georg. Naturgeschichte der Vulcane. Gotha, 1855. 2 vols. 8vo.

Laurent, Ch. Mémoires sur le Sahara Oriental au point de vue des Puits Artésiens. Paris, 1859. 8vo. *pamphlet.* Also, in Mém de la Soc. des Ingénieurs Civils, and the Bulletin de la Soc. Géologique de France.

Laval. Mémoire sur les Dunes du Golfe de Gascogne; in Annales des Ponts et Chaussées, 1847, 2me sémestre, pp. 218–268.

Lavergne, M. L. de. Économie Rurale de la France, depuis 1789. 2me édition, Paris, 1861. 12mo.

Le Alpi che cingono l'Italia. Parte 1er, vol. 1er. Torino, 1845. 8vo.

Lefort. Notice sur les travaux de Fixation des Dunes; in Annales des Ponts et Chaussées, 1831, 2me sémestre, pp. 320–332.

Lenormant. Note relative à l'Execution d'un Puits Artésien en Egypte sous la XVIII^{me} Dynastie; Académie des Inscriptions et Belles-Lettres, 12 Novembre, 1852.

Liber Albus: The White Book of the City of London. London, 1861. 4to.

Loftus, W. K. Travels and Researches in Chaldæa and Susiana. New York, 1857. 8vo.

Lombardini. Cenni Idrografi sulla Lombardia; Intorno al Sistema Idraulico del Pô; epitomized by Baumgarten in Annales des Ponts et Chaussées. 1847, 1er sémestre, pp. 129, 199; and in Dumont, Des Travaux Publics, pp. 268, 335.

——— Sui progetti intesi ad estendere l'irrigazione della Pianura del Pô. Politecnico. Gennajo, 1863, pp. 5–50.

Lorentz. Cours Élémentaire de Culture des Bois, complété et publie par A. Parade, 4me edition. Paris et Nancy, 1860. 8vo.

Lyell, Sir Charles. The Geological Evidence of the Antiquity of Man. London, 1863. 8vo. Principles of Geology. New York, 1862. 8vo.

Mardigny, M. de. Mémoire sur les Inondations des Rivières de l'Ardèche. Paris, 1860. 8vo.

Marschand, A. Ueber die Entwaldung der Gebirge. Bern, 1849. 12mo. *pamphlet.*

Martineau. Endeavors after the Christian Life. Boston, 1858.

Martins. Revue des Deux Mondes, Avril, 1863.

Maury, M. F. The Physical Geography of the Sea. Tenth edition. London, 1861. 8vo.

Medlicott, Dr. Observations of, quoted from London Athenæum, 1863.

Meguscher, Francesco. Memorie sulla migliore maniera per rimettere i Boschi della Lombardia, etc. Milano, 1859. 8vo.

Mejdell, Th. Om Foranstaltninger til Behandling af Norges Skove. Christiania, 1858. 8vo.

Mella. Delle Inondazioni del Mella nella notte del 14 al 15 Agosto, 1850. Brescia, 1851. 8vo.

Meyer, J. Physik der Schweiz. Leipzig, 1854. 8vo.

Michelet, J. L'Insecte, 4me edition. Paris, 1860. 12mo.

——— L'Oiseau, 7me edition. Paris, 1861. 12mo.

Monestier-Savignat, A. Étude sur les Phénomènes, l'Aménagement et la Législation des Eaux au point de vue des Inondations. Paris, 1858. 8vo.

Montluisant. Note sur les Desséchements, les Endiguements et les Irrigations; in Annales des Ponts et Chaussées, 1833, 2me sémestre, pp. 281–294.

Morozzi, Ferdinando. Dello Stato Antico e Moderno del Fiume Arno. Firenze, 1762. 4to.

Müller, K. Das Buch der Pflanzenwelt. Leipzig, 1857. 2 vols. 12mo.

Nangis, Guillaume de. Extracts from, in Nouvelle Collection des Mémoires pour servir par Michaud et Poujoulat. Vol. i. Paris, 1836.

Nanquette, Henri. Cours d'Aménagement des Forêts. Paris et Nancy, 1860. 8vo.

Newberry, Dr. Report in Pacific Railroad Report, vol. vi.

Niebelunge-Lied, Der. Abdruck der Handschrift von Joseph von Lassberg. Leipzig, 1840. Folio.

Niel. L'Agriculture des États Sardes. Turin, 1857. 8vo.

Pacific Railroad Report. Reports of Explorations and Surveys for a Railroad Route to the Pacific. Washington, various years. 12 vols. 4to.

Palissy, Bernard. Œuvres Complètes, avec des Notes, etc., par Paul-Antoine Cap. Paris, 1844. 12mo.

Parade, A. See *Lorentz.*

Paramelle, Abbé. Quellenkunde, Lehre von der Bildung und Auffindung der Quellen; mit einem Vorwort von B. Cotta. Leipzig, 1856. 12mo.

Parish, Dr. Life of Dr. Eleazer Wheelock. 8vo.

Parry, C. C. Report in United States and Mexican Boundary Survey, vol. i.

Parthey, G. Wanderungen durch Sicilien und die Levante. Berlin, 1834. 2 vols. 12mo.

Piper, R. U. The Trees of America. Boston, 1858, Nos. i–iv. 4to.

Plinii, Historia Naturalis, ed. Hardouin. Paris, 1723. 3 vols. folio.

Ponz, Antonio. Viage de España. Madrid, 1788, etc. 18 vols. 12mo.

Quatrefages, A. de. Souvenirs d'un Naturaliste. Paris, 1854. 2 vols. 12mo.

Reclus, Elisée. Le Littoral de la France; Revue des Deux Mondes, 15 Decembre, 1862.

Rentzsch, Hermann. Der Wald im Haushalt der Natur und der Volkswirthschaft. Leipzig, 1862. 8vo.

Ribbe, Charles de. La Provence au point de vue des Bois, des Torrents et des Inondations. Paris, 1857. 8vo.

Ridolfi, Cosimo. Lezioni Orali. Firenze, 1862. 2 vols. 8vo.

Ritter, Carl. Einleitung zur allgemeinen vergleichenden Geographie. Berlin, 1852. 8vo.

——— Die Erdkunde im Verhältniss zur Natur und zur Geschichte des Menschen. Berlin, various years. 19 vols. 8vo.

Rosa, G. Le Condizioni de' boschi, de' fiumi e de' torrenti nella provincia di Bergamo. Politecnico, Dicembre, 1861, pp. 606, 621.

——— Studii sui Boschi. Politecnico, Maggio, 1862, pp. 232, 238.

Rossmässler, C. A. Der Wald. Leipzig und Heidelberg, 1863. 8vo.

Roth, J. Der Vesuv und die Umgebung von Neapel. Berlin, 1857. 8vo.

Rozet, M. Moyens de forcer les Torrents des Montagnes de rendre une partie du sol qu'ils ravagent. Paris, 1856. 8vo. *pamphlet.*

Salvagnoli-Marchetti, Antonio. Memorie Economico-Statistiche sulle Maremme Toscane. Firenze, 1846. 8vo.

——— Raccolta di Documenti sul Bonificamento delle Maremme Toscane. Firenze, 1861. 8vo.

——— Rapporto sul Bonificamento delle Maremme Toscane. Firenze, 1859. 8vo.

——— Rapporto sulle Operazioni Idrauliche ed Economiche eseguite nel 1859–'60 nelle Maremme Toscane. Firenze, 1860. 8vo.

Sandys, George. A Relation of a Journey begun An. Dom. 1610. London, 1627. Folio.

Schacht, H. Les Arbres, Études sur leur Structure et leur Végétation, traduit par E. Morren. Bruxelles et Leipzig, 1862. 8vo.

Schleiden, M. J. Die Landenge von Suës. Leipzig, 1858. 8vo.

——— Die Pflanze und ihr Leben. Leipzig, 1848. 8vo.

Schubert, W. von. Resa genom Sverige, Norrige, Lappland, etc. Stockholm, 1823. 3 vols. 8vo.

Seneca, L. A. Opera Omnia quæ supersunt, ex rec. Ruhkopf. Aug. Taurinorum, 1831. 6 vols. 8vo.

Simonde, J. E. L. Tableau de l'Agriculture Toscane. Genève, 1801. 8vo.

Smith, Dr. William. A Dictionary of the Bible. London, 1860. 3 vols. 8vo.

——— A Dictionary of Greek and Roman Geography. London, 1854, 1857. 2 vols. 8vo.

Smith, John. Historie of Virginia. London, 1624. Folio.

Somerville, Mary. Physical Geography. Fifth edition. London, 1862. 12mo.

Springer, John S. Forest-Life and Forest-Trees. New York, 1851. 12mo.

Stanley, Dr. Lectures on the History of the Jewish Church. London, 1863. 8vo.

Staring, W. H. De Bodem van Nederland. Haarlem, 1856. 2 vols. 8vo.

——— Voormaals en Thans. Haarlem, 1858. 8vo.

Stevens, Gov. Report in Pacific Railroad Report, vol. xii.

Strain, Lieut. I. C. Darien Exploring Expedition, by J. T. Headley, in Harper's Magazine. New York, March, April, and May, 1855.

Streffleur, V. Ueber die Natur und die Wirkungen der Wildbäche. Sitz. Ber. der M. N. W. Classe der Kaiserl. Akad. der Wis. February, 1852, viii, p. 248.

Ström, Isr. Om Skogarnas Vård och Skötsel. Upsala, 1853. *Pamphlet.*

Surell, Alexandre. Étude sur les Torrents des Hautes Alpes. Paris, 1844. 4to.

Tartini, Ferdinando. Memorie sul Bonificamento delle Maremme Toscane. Firenze, 1838. Folio.

Thomas and Baldwin. Gazetteer. Philadelphia, 1855. 1 vol. 8vo.

Thompson, Z. History of Vermont, Natural, Civil, and Statistical. Burlington, 1842. 8vo.

——— Appendix to History of Vermont. Burlington, 1853. 8vo.

Titcomb, Timothy. Lessons in Life. New York, 1861. 12mo.

Treadwell, Dr. Observations of, quoted from Report of Commissioner of Patents.

Troy, Paul. Étude sur le Reboisement des Montagnes. Paris et Toulouse, 1861. 8vo. *pamphlet.*

Tschudi, Friedrich von. Ueber die Landwirthschaftliche Bedeutung der Vögel. St. Gallen, 1854. 12mo.

Tschudi, J. J. von. Travels in Peru. New York, 1848. 8vo.

Vallès, M. F. Études sur les Inondations, leurs causes et leurs effets. Paris, 1857. 8vo.

Valvasor, Johann Weichard. Die Ehre des Herzogthums Crain. Laybach, 1689. 4 vols. folio.

Van Lennep. Extracts from Journal of, in the Missionary Herald.

Vaupell, Chr. Bögens Indvandring i de Danske Skove. Kjöbenhavn, 1857. 8vo.

——— De Nordsjællandske Skovmoser. Kjöbenhavn, 1851. 4to. *pamphlet.*

Venema, G. A. Over het Dalen van de Noordelijke Kuststreken van ons Land. Groningen, 1854. 8vo.

Villa, Antonio Giovanni Batt. Necessità dei Boschi nella Lombardia. Milano, 1850. 4to.

Viollet, J. B. Théorie des Puits Artésiens. Paris, 1840. 8vo.

Waltershausen, W. Sartorius von. Ueber den Sicilianischen Ackerbau Göttingen, 1863.

Webster, Noah. A Collection of Papers on Political, Literary, and Moral Subjects. New York, 1843. 8vo.

Wessely, Joseph. Die Oesterreichischen Alpenländer und ihre Forste. Wien, 1853. 2 vols. 8vo.

Wetzstein, J. G. Reisebericht über Hauran und die Trachonen. Berlin, 1860. 8vo.

Wild, Albert. Die Niederlande. Leipzig, 1862. 2 vols. 8vo.

Wilhelm, Gustav. Der Boden und das Wasser. Wien, 1861. 8vo.

Williams, Dr. History of Vermont. 2 vols. 8vo.

Wittwer, W. C. Die Physikalische Geographie. Leipzig, 1855. 8vo.

Young, Arthur. Voyages en France, pendant les années 1787, 1788, 1789, précédée d'une introduction par Lavergne. Paris, 1860. 2 vols. 12mo.

——— Voyages en Italie et en Espagne, pendant les années 1787, 1789. Paris, 1860. 1 vol. 12mo.

TABLE OF CONTENTS.

CHAPTER I.

INTRODUCTORY.

PAGE

Natural Advantages of the Territory of the Roman Empire—Physical Decay of that Territory—Causes of the Decay—Reaction of Man on Nature—Observation of Nature—Uncertainty of Our Historical Knowledge of Ancient Climates—Uncertainty of Modern Meteorology—Stability of Nature—Formation of Bogs—Natural Conditions Favorable to Geographical Change—Destructiveness of Man—Human and Brute Action Compared—Limits of Human Power—Importance of Physical Conservation and Restoration—Uncertainty as to Effects of Human Action.................................. 1

CHAPTER II.

TRANSFER, MODIFICATION, AND EXTIRPATION OF VEGETABLE AND OF ANIMAL SPECIES.

Modern Geography takes Account of Organic Life—Geographical Importance of Plants—Origin of Domestic Vegetables—Transfer of Vegetable Life—Objects of Modern Commerce—Foreign Plants, how Introduced—Vegetable Power of Accommodation—Agricultural Products of the United States—Useful American Plants Grown in Europe—Extirpation of Vegetables—Animal Life as a Geological and Geographical Agency—Origin and Transfer of Domestic Quadrupeds—Extirpation of Wild Quadrupeds—Large Marine Animals Relatively Unimportant in Geography—Introduction and Breeding of Fish—Destruction of Fish—Geographical Importance of Birds—Introduction of Birds—Destruction of Birds—Utility and Destruction of Reptiles—Utility of Insects and Worms—Injury to the Forest by Insects—Introduction of Insects—Destruction of Insects—Minute Organisms... 56

CHAPTER III.

THE WOODS.

PAGE

The Habitable Earth Originally Wooded—General Meteorological Influence of the Forest—Electrical Action of Trees—Chemical Influence of Woods—Trees as Protection against Malaria—Trees as Shelter to Ground to the Leeward—Influence of the Forest as Inorganic on Temperature—Thermometrical Action of Trees as Organic—Total Influence of the Forest on Temperature—Influence of Forests as Inorganic on Humidity of Air and Earth—Influence as Organic—Balance of Conflicting Influences—Influence of Woods on Precipitation—Total Climatic Action of the Forest—Influence of the Forest on Humidity of Soil—The Forest in Winter—Summer Rain, Importance of—Influence of the Forest on the Flow of Springs—Influence of the Forest on Inundations and Torrents—Destructive Action of Torrents—Floods of the Ardèche—Excavation by Torrents—Extinction of Torrents—Crushing Force of Torrents—Transporting Power of Water—The Po and its Deposits—Mountain Slides—Forest as Protection against Avalanches—Minor Uses of the Forest—Small Forest Plants and Vitality of Seeds—Locusts do not Breed in Forests—General Functions of Forest—General Consequences of Destruction of—Due Proportion of Woodland—Proportion of Woodland in European Countries—Forests of Great Britain—Forests of France—Forests of Italy—Forests of Germany—Forests of United States—American Forest Trees—European and American Forest Trees Compared—The Forest does not furnish Food for Man—First Removal of the Forest—Principal Causes of Destruction of Forest—Destruction and Protection of Forests by Governments—Royal Forests and Game-laws—Effects of the French Revolution—Increased Demand for Lumber—Effects of Burning Forest—Floating of Timber—Restoration of the Forest—Economy of the Forest—Forest Legislation—Plantation of Forests in America—Financial Results of Forest Plantations—Instability of American Life.. 148

CHAPTER IV.

THE WATERS.

Land Artificially Won from the Waters—Great Works of Material Improvement—Draining of Lincolnshire Fens—Incursions of the Sea in the Netherlands—Origin of Sea-dikes—Gain and Loss of Land in the Netherlands—Marine Deposits on the Coast of Netherlands—Draining of Lake of Haarlem—Draining of the Zuiderzee—Geographical Effects of

PAGE

Improvements in the Netherlands—Ancient Hydraulic Works—Draining of Lake Celano by Prince Torlonia—Incidental Consequences of Draining Lakes—Draining of Marshes—Agricultural Draining—Meteorological Effects of Draining—Geographical Effects of Draining—Geographical Effects of Aqueducts and Canals—Antiquity of Irrigation—Irrigation in Palestine, India, and Egypt—Irrigation in Europe—Meteorological Effects of Irrigation—Water withdrawn from Rivers for Irrigation—Injurious Effects of Rice-culture—Salts Deposited by Water of Irrigation—Subterranean Waters—Artesian Wells—Artificial Springs—Economizing Precipitation—Inundations in France—Basins of Reception—Diversion of Rivers—Glacier Lakes—River Embankments—Other Remedies against Inundations—Dikes of the Nile—Deposits of Tuscan Rivers—Improvements in Tuscan Maremma—Improvements in Val di Chiana—Coast of the Netherlands.......... .. 398

CHAPTER V.

THE SANDS.

Origin of Sand—Sand now Carried to the Sea—Beach Sands of Northern Africa—Sands of Egypt—Sand Dunes and Sand Plains—Coast Dunes—Sand Banks—Character of Dune Sand—Interior Structure of Dunes—Geological Importance of Dunes—Dunes on American Coasts—Dunes of Western Europe—Age, Character, and Permanence of Dunes—Dunes as a Barrier against the Sea—Encroachments of the Sea—Liimfjord—Coasts of Schleswig-Holstein, Netherlands, and France—Movement of Dunes—Control of Dunes by Man—Inland Dunes—Inland Sand Plains.. 545

CHAPTER VI.

GREAT PROJECTS OF PHYSICAL CHANGE ACCOMPLISHED OR PROPOSED BY MAN.

Cutting of Isthmuses—Canal of Suez—Maritime Canals in Greece—Canals to Dead Sea—Canals to Libyan Desert—Maritime Canals in Europe—Cape Cod Canal—Changes in Caspian—Diversion of the Nile—Diversion of the Rhine—Improvements in North American Hydrography—Soil below Rock—Covering Rock with Earth—Desert Valleys—Effects of Mining—Duponchel's Plans of Improvement—Action of Man on the Weather—Resistance to Great Natural Forces—Incidental Effects of Human Action—Nothing Small in Nature................. 609

THE EARTH

AS MODIFIED BY HUMAN ACTION.

LIFFE LIBRARY

CHAPTER I.

INTRODUCTORY.

Natural Advantages of the Territory of the Roman Empire.—Physical Decay of that Territory.—Causes of the Decay.—Reaction of Man on Nature.—Observation of Nature.—Uncertainty of Our Historical Knowledge of Ancient Climates.—Uncertainty of Modern Meteorology.—Stability of Nature.—Formation of Bogs.—Natural Conditions Favorable to Geographical Change.—Destructiveness of Man.—Human and Brute Action Compared.—Limits of Human Power.—Importance of Physical Conservation and Restoration.—Uncertainty as to Effects of Human Action.

Natural Advantages of the Territory of the Roman Empire.

The Roman Empire, at the period of its greatest expansion, comprised the regions of the earth most distinguished by a happy combination of physical conditions. The provinces bordering on the principal and the secondary basins of the Mediterranean enjoyed in healthfulness and equability of climate, in fertility of soil, in variety of vegetable and mineral products, and in natural facilities for the transportation and distribution of exchangeable commodities, advantages which have not been possessed in any equal degree by any territory of like extent in the Old World or the New. The abundance of the land and of the waters adequately supplied every material want, ministered liberally to every sensuous enjoyment. Gold and silver, indeed, were not found in the profusion which has proved so baneful to the industry of lands richer in veins of the precious metals; but mines and river beds yielded them in the spare measure most favorable to stability of value in the medium of exchange, and, consequently, to the regularity of commercial transactions. The ornaments of the barbaric pride of the East, the pearl, the ruby, the sapphire, and the diamond—though not unknown to the luxury of a people whose conquests and whose wealth commanded whatever the habitable world could contribute to augment the material splendor of their social life—were scarcely native to the territory of the empire; but the comparative rarity of these gems in Europe, at somewhat earlier periods, was, perhaps, the very circumstance that led the cunning artists of classic antiquity to enrich softer stones with engravings, which invest the common onyx and cornelian with a worth surpassing, in cultivated eyes, the lustre of the most brilliant oriental jewels.

Of these manifold blessings the temperature of the air, the distribution of the rains, the relative disposition of land and water, the plenty of the sea, the composition of the soil, and the raw material of the primitive arts, were wholly gratuitous gifts. Yet the spontaneous nature of Europe, of Western Asia, of Libya, neither fed nor clothed the civilized inhabitants of those provinces. The luxuriant harvests of cereals that waved on every field from the shores of the Rhine to the banks of the Nile, the vines that festooned the hillsides of Syria, of Italy and of Greece, the olives of Spain, the fruits of the gardens of the Hesperides, the domestic quadrupeds and fowls known in ancient rural husbandry—all these were original products of foreign climes, naturalized in new homes, and gradually ennobled by the art of man, while centuries of persevering labor were expelling the wild vegetation, and fitting the earth for the production of more generous growths. Every loaf was eaten in the sweat of the brow. All must be earned by toil. But toil was nowhere else rewarded by so generous wages; for nowhere would a given amount of intelligent labor produce so abundant, and, at the same time, so varied returns of the good things of material existence.

Physical Decay of the Territory of the Roman Empire.

If we compare the present physical condition of the countries of which I am speaking, with the descriptions that ancient historians and geographers have given of their fertility and general capability of ministering to human uses, we shall find that more than one-half their whole extent—not excluding the provinces most celebrated for the profusion and variety of their spontaneous and their cultivated products, and for the wealth and social advancement of their inhabitants—is either deserted by civilized man and surrendered to hopeless desolation, or at least greatly reduced in both productiveness and population. Vast forests have disappeared from mountain spurs and ridges; the vegetable earth accumulated beneath the trees by the decay of leaves and fallen trunks, the soil of the alpine pastures which skirted and indented the woods, and the mould of the upland fields, are washed away; meadows, once fertilized by irrigation, are waste and unproductive because the cisterns and reservoirs that supplied the ancient canals are broken, or the springs that fed them dried up; rivers famous in history and song have shrunk to humble brooklets; the willows that ornamented and protected the banks of the lesser watercourses are gone, and the rivulets have ceased to exist as perennial currents, because the little water that finds its way into their old channels is evaporated by the droughts of summer, or absorbed by the parched earth before it reaches the lowlands; the beds of the brooks have widened into broad expanses of pebbles and gravel, over which, though in the hot season passed dryshod, in winter sealike torrents thunder; the entrances of navigable streams are obstructed by sandbars; and harbors, once marts of an extensive commerce, are shoaled by the deposits of the rivers at whose mouths they lie; the elevation of the beds of estuaries, and the consequently diminished velocity and increased lateral spread of the streams which flow into them, have converted thousands of leagues of shallow sea and fertile lowland into unproductive and miasmatic morasses.

Besides the direct testimony of history to the ancient fertility of the now exhausted regions to which I refer—Northern Africa, the greater Arabian peninsula, Syria, Mesopotamia, Armenia and many other provinces of Asia Minor, Greece, Sicily, and parts of even Italy and Spain—the multitude and extent of yet remaining architectural ruins, and of decayed works of internal improvement, show that at former epochs a dense population inhabited those now lonely districts. Such a population could have been sustained only by a productiveness of soil of which we at present discover but slender traces; and the abundance derived from that fertility serves to explain how large armies, like those of the ancient Persians, and of the Crusaders and the Tartars in later ages, could, without an organized commissariat, secure adequate supplies in long marches through territories which, in our times, would scarcely afford forage for a single regiment.

It appears then, that the fairest and fruitfulest provinces of the Roman Empire, precisely that portion of terrestrial surface, in short, which, about the commencement of the Christian era, was endowed with the greatest superiority of soil, climate, and position, which had been carried to the highest pitch of physical improvement, and which thus combined the natural and artificial conditions best fitting it for the habitation and enjoyment of a dense and highly refined and cultivated population, are now completely exhausted of their fertility, or so diminished in productiveness, as, with the exception of a few favored oases that have escaped the general ruin, to be no longer capable of affording sustenance to civilized man. If to this realm of desolation we add the now wasted and solitary soils of Persia and the remoter East that once fed their millions with milk and honey, we shall see that a territory larger than all Europe, the abundance of which sustained in bygone centuries a population scarcely inferior to that of the whole Christian world at the present day, has been entirely withdrawn from human use, or, at best, is thinly inhabited by tribes too few in numbers, too poor in superfluous products, and too little advanced in culture and the social arts, to contribute anything to the general moral or material interests of the great commonwealth of man.

Causes of this Decay.

The decay of these once flourishing countries is partly due, no doubt, to that class of geological causes whose action we can neither resist nor guide, and partly also to the direct violence of hostile human force; but it is, in a far greater proportion, either the result of man's ignorant disregard of the laws of nature, or an incidental consequence of war and of civil and ecclesiastical tyranny and misrule. Next to ignorance of these laws, the primitive source, the *causa causarum*, of the acts and neglects which have blasted with sterility and physical decrepitude the noblest half of the empire of the Cæsars, is, first, the brutal and exhausting despotism which Rome herself exercised over her conquered kingdoms, and even over her Italian territory; then, the host of temporal and spiritual tyrannies which she left as her dying curse to all her wide dominion, and which, in some form of violence or of fraud, still brood over almost every soil subdued by the Roman legions.* Man cannot struggle at once against human oppression and the destructive forces of inorganic nature. When both are combined against him, he succumbs after a shorter or longer struggle, and the fields he has won from the primeval wood relapse into their original state of wild and luxuriant, but unprofitable forest growth, or fall into that of a dry and barren wilderness.

---

* In the Middle Ages, feudalism, and a nominal Christianity, whose corruptions had converted the most beneficent of religions into the most baneful of superstitions, perpetuated every abuse of Roman tyranny, and added new oppressions and new methods of extortion to those invented by older despotisms. The burdens in question fell most heavily on the provinces that had been longest colonized by the Latin race, and these are the portions of Europe which have suffered the greatest physical degradation. "Feudalism," says Blanqui, "was a concentration of scourges. The peasant, stripped of the inheritance of his fathers, became the property of inflexible, ignorant, indolent masters; he was obliged to travel fifty leagues with their carts whenever they required it; he labored for them three days in the week, and surrendered to them half the product of his earnings during the other three; without their consent he could not change his residence, or marry. And why, indeed, should he wish to marry, when he could scarcely save enough to maintain

---

himself? The Abbot Alcuin had twenty thousand slaves, called *serfs*, who were forever attached to the soil. This is the great cause of the rapid depopulation observed in the Middle Ages, and of the prodigious multitude of monasteries which sprang up on every side. It was doubtless a relief to such miserable men to find in the cloisters a retreat from oppression; but the human race never suffered a more cruel outrage, industry never received a wound better calculated to plunge the world again into the darkness of the rudest antiquity. It suffices to say that the prediction of the approaching end of the world, industriously spread by the rapacious monks at this time, was received without terror."—*Résumé de l'Histoire du Commerce*, p. 156.

The abbey of Saint-Germain-des-Prés, which, in the time of Charlemagne, had possessed a million of acres, was, down to the Revolution, still so wealthy, that the personal income of the abbot was 300,000 livres. The abbey of Saint-Denis was nearly as rich as that of Saint-Germain-des-Prés.—LAVERGNE, *Économie Rurale de la France*, p. 104.

Paul Louis Courier quotes from La Bruyère the following striking picture of the condition of the French peasantry in his time: "One sees certain dark, livid, naked, sunburnt, wild animals, male and female, scattered over the country and attached to the soil, which they root and turn over with indomitable perseverance. They have, as it were, an articulate voice, and when they rise to their feet, they show a human face. They are, in fact, men; they creep at night into dens, where they live on black bread, water, and roots. They spare other men the labor of ploughing, sowing, and harvesting, and therefore deserve some small share of the bread they have grown." "These are his own words," adds Courier, "and he is speaking of the *fortunate* peasants, of those who had work and bread, and they were then the few."—*Pétition à la Chambre des Députés pour les Villageois que l'en empêche de danser.*

Arthur Young, who travelled in France from 1787 to 1789, gives, in the twenty-first chapter of his Travels, a frightful account of the burdens of the rural population even at that late period. Besides the regular governmental taxes, and a multitude of heavy fines imposed for trifling offences, he enumerates about thirty seignorial rights, the very origin and nature of some of which are now unknown, while those of some others are as repulsive to humanity and morality, as the worst abuses ever practised by heathen despotism. But Young underrates the number of these oppressive impositions. Moreau de Jonnès, a higher authority, asserts that in a brief exam-

Rome imposed on the products of agricultural labor in the rural districts taxes which the sale of the entire harvest would scarcely discharge; she drained them of their population by military conscription; she impoverished the peasantry by forced and unpaid labor on public works; she hampered industry and both foreign and internal commerce by absurd restrictions and unwise regulations.* Hence, large tracts of land were left uncultivated, or altogether deserted, and exposed to all the destructive forces which act with such energy on the surface of the earth when it is deprived of those protections by which nature originally guarded it, and for which, in well-ordered husbandry, human ingenuity has contrived more or less efficient substitutes.† Similar abuses have tended to perpetuate and extend these evils in later ages, and it is but recently that, even in the most populous parts of Europe, public attention

---

ination he had discovered upwards of three hundred distinct rights of the feudatory over the person or the property of his vassal. See *État Économique et Social de la France*, Paris, 1870, p. 389. Most of these, indeed, had been commuted for money payments, and were levied on the peasantry as pecuniary imposts for the benefit of prelates and lay lords, who, by virtue of their nobility, were exempt from taxation. The collection of the taxes was enforced with unrelenting severity. On one occasion, in the reign of Louis XIV., the troops sent out against the recreant peasants made more than 3,000 prisoners, of whom 400 were condemned to the galleys for life, and a number so large that the government did not dare to disclose it, were hung on trees or broken on the wheel.—Moreau de Jonnès, *État Économique et Social de la France*, p. 420. Who can wonder at the hostility of the French plebeian classes towards the aristocracy in the days of the Revolution?

* Commerce, in common with all gainful occupations except agriculture, was despised by the Romans, and the exercise of it was forbidden to the higher ranks. Cicero, however, admits that though retail trade, which could only prosper by lying and knavery, was contemptible, yet wholesale commerce was not altogether to be condemned, and might even be laudable, provided the merchant retired early from trade and invested his gains in farm lands.—*De Officiis*, lib. i., 42.

† The temporary depopulation of an exhausted soil may be, in some cases, a physical, though, like fallows in agriculture, a dear-bought advantage. Under favorable circumstances, the withdrawal of man and his flocks allows the earth to clothe itself again with forests, and in a few generations to recover its ancient productiveness. In the Middle Ages, worn-out fields were

has been half awakened to the necessity of restoring the disturbed harmonies of nature, whose well-balanced influences are so propitious to all her organic offspring, and of repaying to our great mother the debt which the prodigality and the thriftlessness of former generations have imposed upon their successors—thus fulfilling the command of religion and of practical wisdom, to use this world as not abusing it.

Reaction of Man on Nature.

The revolutions of the seasons, with their alternations of temperature and of length of day and night, the climates of different zones, and the general conditions and movements of the atmosphere and the seas, depend upon causes for the most part cosmical, and, of course, wholly beyond our control. The elevation, configuration, and composition of the great masses of terrestrial surface, and the relative extent and distribution of land and water, are determined by geological influences equally remote from our jurisdiction. It would hence seem that the physical adaptation of different portions of the earth to the use and enjoyment of man is a matter so strictly belonging to mightier than human powers, that we can only accept geographical nature as we find her, and be content with such soils and such skies as she spontaneously offers.

But it is certain that man has reacted upon organized and inorganic nature, and thereby modified, if not determined, the material structure of his earthly home. The measure of that reaction manifestly constitutes a very important element in the appreciation of the relations between mind and matter, as well as in the discussion of many purely physical problems. But though the subject has been incidentally touched upon by

---

depopulated, in many parts of the Continent, by civil and ecclesiastical tyrannies, which insisted on the surrender of the half of a loaf already too small to sustain its producer. Thus abandoned, these lands often relapsed into the forest state, and, some centuries later, were again brought under cultivation with renovated fertility.

many geographers, and treated with much fulness of detail in regard to certain limited fields of human effort and to certain specific effects of human action, it has not, as a whole, so far as I know, been made matter of special observation, or of historical research, by any scientific inquirer. Indeed, until the influence of geographical conditions upon human life was recognized as a distinct branch of philosophical investigation, there was no motive for the pursuit of such speculations; and it was desirable to inquire how far we have, or can, become the architects of our own abiding place, only when it was known how the mode of our physical, moral, and intellectual being is affected by the character of the home which Providence has appointed, and we have fashioned, for our material habitation.*

It is still too early to attempt scientific method in discussing this problem, nor is our present store of the necessary facts by any means complete enough to warrant me in promising any approach to fulness of statement respecting them. Systematic observation in relation to this subject has hardly yet begun, and the scattered data which have chanced to be recorded have never been collected. It has now no place in the general scheme of physical science, and is matter of suggestion and speculation only, not of established and positive conclusion. At present, then, all that I can hope is to excite an interest in a topic of much economical importance, by pointing out the directions and illustrating the modes in which human action has been, or may be, most injurious or most beneficial in its influence upon the physical conditions of the earth we inhabit.

We cannot always distinguish between the results of man's action and the effects of purely geological or cosmical causes. The destruction of the forests, the drainage of lakes and marshes, and the operations of rural husbandry and industrial art have unquestionably tended to produce great changes in the hygrometric, thermometric, electric, and chemical condition of the atmosphere, though we are not yet able to measure the force of the different elements of disturbance, or to say how far they have been neutralised by each other, or by still obscurer influences; and it is equally certain that the myriad forms of animal and vegetable life, which covered the earth when man first entered upon the theatre of a nature whose harmonies he was destined to derange, have been, through his interference, greatly changed in numerical proportion, sometimes much modified in form and product, and sometimes entirely extirpated.*

---

* Gods Almagt wenkte van den troon,
En schiep elk volk een land ter woon:
Hier vestte Zij een grondgebied,
Dat Zij ons zelven scheppen liet.

---

* Man has not only subverted the natural numerical relations of wild as well as domestic quadrupeds, fish, birds, reptiles, insects, and common plants, and even of still humbler tribes of animal and vegetable life, but he has effected in the forms, habits, nutriment and products of the organisms which minister to his wants and his pleasures, changes which, more than any other manifestation of human energy, resemble the exercise of a creative power. Even wild animals have been compelled by him, through the destruction of plants and insects which furnished their proper aliment, to resort to food belonging to a different kingdom of nature. Thus a New Zealand bird, originally granivorous and insectivorous, has become carnivorous, from the want of its natural supplies, and now tears the fleeces from the backs of the sheep, in order to feed on their living flesh.

All these changes have exercised more or less direct or indirect action on the inorganic surface of the globe; and the history of the geographical revolutions thus produced would furnish ample material for a volume.

The modification of organic species by domestication is a branch of philosophic inquiry which we may almost say has been created by Darwin; but the geographical results of these modifications do not appear to have yet been made a subject of scientific investigation.

I do not know that the following passage from Pliny has ever been cited in connection with the Darwinian theories, but it is worth a reference:

"But behold a very strange and new fashion of them [cucumbers] in Campane, for there you shall have abundance of them come up in forme of a Quince. And as I heare say, one of them chaunced so to grow first at a very venture; but afterwards from the seed of it came a whole race and progenie of the like, which therefore they call Melopopones, as a man would say, the Quince-pompions or cucumbers."—PLINY, *Nat. Hist.*, Holland's translation, book xix., c. 5.

The word *cucumis* used in the original of this passage embraces many of the cucurbitaceæ, but the context shows that it here means the cucumber.

The physical revolutions thus wrought by man have not indeed all been destructive to human interests, and the heaviest blows he has inflicted upon nature have not been wholly without their compensations. Soils to which no nutritious vegetable was indigenous, countries which once brought forth but the fewest products suited for the sustenance and comfort of man—while the severity of their climates created and stimulated the greatest number and the most imperious urgency of physical wants—surfaces the most rugged and intractable, and least blessed with natural facilities of communication, have been brought in modern times to yield and distribute all that supplies the material necessities, all that contributes to the sensuous enjoyments and conveniences of civilized life. The Scythia, the Thule, the Britain, the Germany, and the Gaul which the Roman writers describe in such forbidding terms, have been brought almost to rival the native luxuriance and easily won plenty of Southern Italy; and, while the fountains of oil and wine that refreshed old Greece and Syria and Northern Africa have almost ceased to flow, and the soils of those fair lands are turned to thirsty and inhospitable deserts, the hyperborean regions of Europe have learned to conquer, or rather compensate, the rigors of climate, and have attained to a material wealth and variety of product that, with all their natural advantages, the granaries of the ancient world can hardly be said to have enjoyed.

Observation of Nature.

In these pages it is my aim to stimulate, not to satisfy, curiosity, and it is no part of my object to save my readers the labor of observation or of thought. For labor is life, and

> Death lives where power lives unused.*

Self is the schoolmaster whose lessons are best worth his wages; and since the subject I am considering has not yet become a branch of formal instruction, those whom it may interest can, fortunately, have no pedagogue but themselves. To the natural philosopher, the descriptive poet, the painter, the sculptor, and indeed every earnest observer, the power most important to cultivate, and, at the same time, hardest to acquire, is that of seeing what is before him. Sight is a faculty; seeing, an art. The eye is a physical but not a self-acting apparatus, and in general it sees only what it seeks. Like a mirror, it reflects objects presented to it; but it may be as insensible as a mirror, and not consciously perceive what it reflects.[*]

---

* Verses addressed by G. C. to Sir Walter Raleigh.—HAKLUYT, i., p. 668.

It has been maintained by high authority, that the natural acuteness of our sensuous faculties cannot be heightened by use, and hence, that the minutest details of the image formed on the retina are as perfect in the most untrained as in the most thoroughly disciplined organ. This may be questioned, and it is agreed on all hands that the power of multifarious perception and rapid discrimination may be immensely increased by well-directed practice.[†] This exercise of the eye

---

[*] ——— I troer, at Synets Sands er lagt i Öiet,
Mens dette kun er Redskab. Synet strömmer
Fra Sjælens Dyb, og Öiets fine Nerver
Gaae ud fra Hjernens hemmelige Værksted.
HENRIK HERTZ, *Kong René's Datter*, sc. ii.

In the material eye, you think, sight lodgeth!
The *eye* is but an organ. *Seeing* streameth
From the soul's inmost depths. The fine perceptive
Nerve springeth from the brain's mysterious workshop.

[†] Skill in marksmanship, whether with firearms or with other projectile weapons, depends more upon the training of the eye than is generally supposed, and I have often found particularly good shots to possess an almost telescopic vision. In the ordinary use of the rifle, the barrel is guided by the eye, but there are sportsmen who fire with the butt of the gun at the hip. In this case, as in the use of the sling, the lasso, and the bolas, in hurling the knife (see BABINET, *Lectures*, vii., p. 84), in throwing the boomerang, the javelin, or a stone, and in the employment of the blowpipe and the bow, the movements of the hand and arm are guided by that mysterious sympathy which exists between the eye and the unseeing organs of the body.

"Some men wonder whye, in casting a man's eye at the marke, the hand

I desire to promote, and, next to moral and religious doctrine, I know no more important practical lessons in this earthly life of ours—which, to the wise man, is a school from the cradle to the grave—than those relating to the employment of the sense of vision in the study of nature.

The pursuit of physical geography, embracing actual observation of terrestrial surface, affords to the eye the best general training that is accessible to all. The majority of even cultivated men have not the time and means of acquiring anything beyond a very superficial acquaintance with any branch of physical knowledge. Natural science has become so vastly extended, its recorded facts and its unanswered questions so immensely multiplied, that every strictly scientific man must be a specialist, and confine the researches of a whole life within a comparatively narrow circle. The study I am recommending, in the view I pro-

---

should go streighte. Surely if he considered the nature of a man's eye he would not wonder at it: for this I am certaine of, that no servaunt to his maister, no childe to his father, is so obedient, as every joynte and peece of the bodye is to do whatsover the eye biddes."—ROGER ASCHAM, *Toxophilus*, Book ii.

In shooting the tortoises of the Amazon and its tributaries, the Indians use an arrow with a long twine and a float attached to it. Avé-Lallemant (*Die Benutzung der Palmen am Amazonenstrom*, p. 32) thus describes their mode of aiming: "As the arrow, if aimed directly at the floating tortoise, would strike it at a small angle and glance from its flat and wet shell, the archers have a peculiar method of shooting. They are able to calculate exactly their own muscular effort, the velocity of the stream, the distance and size of the tortoise, and they shoot the arrow directly up into the air, so that it falls almost vertically upon the shell of the tortoise, and sticks in it." Analogous calculations—if such physico-mental operations can properly be so called—are made in the use of other missiles; for no projectile flies in a right line to its mark. But the exact training of the eye lies at the bottom of them all, and marksmanship depends almost wholly upon the power of that organ, whose directions the blind muscles implicitly follow. Savages accustomed only to the use of the bow become good shots with firearms after very little practice. It is perhaps not out of place to observe here that our English word *aim* comes from the Latin *æstimo*, I calculate or estimate. See WEDGWOOD'S *Dictionary of English Etymology*, and the note to the American edition, under *Aim*.

Another proof of the control of the limbs by the eye has been observed in pose to take of it, is yet in that imperfectly developed state which allows its votaries to occupy themselves with broad and general views attainable by every person of culture, and it does not now require a knowledge of special details which only years of application can master. It may be profitably pursued by all; and every traveller, every lover of rural scenery, every agriculturist, who will wisely use the gift of sight, may add valuable contributions to the common stock of knowledge on a subject which, as I hope to convince my readers, though long neglected, and now inartificially presented, is not only a very important but a very interesting field of inquiry.

Measurement of Man's Influence.

The exact measurement of the geographical and climatic changes hitherto effected by man is impracticable, and we possess, in relation to them, the means of only qualitative, not quantitative analysis. The fact of such revolutions is established

---

deaf-and-dumb schools, and others where pupils are first taught to write on large slates or blackboards. The writing is in large characters, the small letters being an inch or more high. They are formed with chalk or a slate pencil firmly grasped in the fingers, and by appropriate motions of the wrist, elbow, and shoulder, not of the finger joints. Nevertheless, when a pen is put into the hand of a pupil thus taught, his handwriting, though produced by a totally different set of muscles and muscular movements, is identical in character with that which he has practised on the blackboard.

For a very remarkable account of the restoration of vision impaired from age, by judicious training, see *Lessons in Life*, by TIMOTHY TITCOMB, lesson xi.

It has been much doubted whether the artists of the classic ages possessed a more perfect sight than those of modern times, or whether, in executing their minute mosaics and gem engravings, they used magnifiers. Glasses ground convex have been found at Pompeii, but they are too rudely fashioned and too imperfectly polished to have been of any practical use for optical purposes. But though the ancient artists may have had a microscopic vision, their astronomers cannot have had a telescopic power of sight; for they did not discover the satellites of Jupiter, which are often seen with the naked eye at Oormeeah, in Persia, and sometimes, as I can testify by personal observation, at Cairo.

partly by historical evidence, partly by analogical deduction from effects produced, in our own time, by operations similar in character to those which must have taken place in more or less remote ages of human action. Both sources of information are alike defective in precision; the latter, for general reasons too obvious to require specification; the former, because the facts to which it bears testimony occurred before the habit or the means of rigorously scientific observation upon any branch of physical research, and especially upon climatic changes, existed.

Uncertainty of our Historical Conclusions on Ancient Climates.

The invention of measures of heat and of atmospheric moisture, pressure, and precipitation, is extremely recent. Hence, ancient physicists have left us no thermometric or barometric records, no tables of the fall, evaporation, and flow of waters, and even no accurate maps of coast lines and the course of rivers. Their notices of these phenomena are almost wholly confined to excessive and exceptional instances of high or of low temperatures, extraordinary falls of rain and snow, and unusual floods or droughts. Our knowledge of the meteorological condition of the earth, at any period more than two centuries before our own time, is derived from these imperfect details, from the vague statements of ancient historians and geographers in regard to the volume of rivers and the relative extent of forest and cultivated land, from the indications furnished by the history of the agriculture and rural economy of past generations, and from other almost purely casual sources of information.*

---

* The subject of climatic change, with and without reference to human action as a cause, has been much discussed by Moreau de Jonnès, Dureau de la Malle, Arago, Humboldt, Fuster, Gasparin, Becquerel, Schleiden, and many other writers in Europe, and by Noah Webster, Forry, Drake, and others in America. Fraas has endeavored to show, by the history of vegetation in Greece, not merely that clearing and cultivation have affected climate, but that change of climate has essentially modified the character of vegetable life. See his *Klima und Pflanzenwelt in der Zeit.*

Among these latter we must rank certain newly laid open fields of investigation, from which facts bearing on the point now under consideration have been gathered. I allude to the discovery of artificial objects in geological formations older than any hitherto recognized as exhibiting traces of the existence of man; to the ancient lacustrine habitations of Switzerland and of the *terremare* of Italy,* containing the implements of the occupants, remains of their food, and other relics of human life; to the curious revelations of the Kjökkenmöddinger, or heaps of kitchen refuse, in Denmark and elsewhere, and of the peat mosses in the same and other northern countries; to the dwellings and other evidences of the industry of man in remote ages sometimes laid bare by the movement of sand dunes on the coasts of France and of the North Sea; and to the facts disclosed on the tide-washed flats of the latter shores by excavations in Halligs or inhabited mounds which were probably raised before the era of the Roman Empire.† These remains are memorials of races which have left no written records, which perished at a period beyond the reach of even historical tradition. The plants and animals that furnished the relics found in the deposits were certainly contemporaneous with man; for they are associated with his works, and have evidently served his uses. In some cases, the animals belonged to species well ascertained to be now altogether extinct; in some others, both the animals and the vegetables, though extant elsewhere, have ceased to inhabit the regions where their remains are discovered. From the character of the artificial objects, as compared with others belonging to known dates, or at least to known periods of civilization, ingenious inferences have been drawn as to their age; and from the vegetable remains which accompany them, as to the climates of Central and Northern Europe at the time of their production.

---

* See two learned articles by Pigorini, in the *Nuova Antologia* for January and October, 1870.

† For a very picturesque description of the Halligs, see PLINY, *N. H.*, Book xvi., c. 1.

There are, however, sources of error which have not always been sufficiently guarded against in making these estimates. When a boat, composed of several pieces of wood fastened together by pins of the same material, is dug out of a bog, it is inferred that the vessel, and the skeletons and implements found with it, belong to an age when the use of iron was not known to the builders. But this conclusion is not warranted by the simple fact that metals were not employed in its construction; for the Nubians at this day build boats large enough to carry half a dozen persons across the Nile, out of small pieces of acacia wood pinned together entirely with wooden bolts, and large vessels of similar construction are used by the islanders of the Malay archipelago. Nor is the occurrence of flint arrow heads and knives, in conjunction with other evidences of human life, conclusive proof as to the antiquity of the latter. Lyell informs us that some Oriental tribes still continue to use the same stone implements as their ancestors, "after that mighty empires, where the use of metals in the arts was well known, had flourished for three thousand years in their neighborhood;" * and the North American Indians now manufacture weapons of stone, and even of glass, chipping them in the latter case out of the bottoms of thick bottles, with great facility.†

We may also be misled by our ignorance of the commercial relations existing between savage tribes. Extremely rude

---

* *Antiquity of Man*, p. 377.

† "One of the Indians seated himself near me, and made from a fragment of quartz, with a simple piece of round bone, one end of which was hemispherical, with a small crease in it (as if worn by a thread) the sixteenth of an inch deep, an arrow head which was very sharp and piercing, and such as they use on all their arrows. The skill and rapidity with which it was made, without a blow, but by simply breaking the sharp edges with the creased bone by the strength of his hands—for the crease merely served to prevent the instrument from slipping, affording no leverage—was remarkable."—*Reports of Explorations and Surveys for Pacific Railroad*, vol. ii., 1855, *Lieut.* BECKWITH's *Report*, p. 43. See also *American Naturalist* for May, 1870, and especially STEVENS, *Flint Chips*, London, 1870, pp. 77 et seq.

Mariette Bey lately saw an Egyptian barber shave the head of an Arab with a flint razor.

nations, in spite of their jealousies and their perpetual wars, sometimes contrive to exchange the products of provinces very widely separated from each other. The mounds of Ohio contain pearls, thought to be marine, which must have come from the Gulf of Mexico, or perhaps even from California, and the knives and pipes found in the same graves are often formed of far-fetched material, that was naturally paid for by some home product exported to the locality whence the material was derived. The art of preserving fish, flesh, and fowl by drying and smoking is widely diffused, and of great antiquity. The Indians of Long Island Sound are said to have carried on a trade in dried shell fish with tribes residing very far inland. From the earliest ages, the inhabitants of the Faroe and Orkney Islands, and of the opposite mainland coasts, have smoked wild fowl and other flesh. Hence it is possible that the animal and the vegetable food, the remains of which are found in the ancient deposits I am speaking of, may sometimes have been brought from climates remote from that where it was consumed.

The most important, as well as the most trustworthy conclusions with respect to the climate of ancient Europe and Asia, are those drawn from the accounts given by the classical writers of the growth of cultivated plants; but these are by no means free from uncertainty, because we can seldom be sure of an identity of species, almost never of an identity of race or variety, between vegetables known to the agriculturists of Greece and Rome and those of modern times which are thought most nearly to resemble them. Besides this, there is always room for doubt whether the habits of plants long grown in different countries may not have been so changed by domestication or by natural selection, that the conditions of temperature and humidity which they required twenty centuries ago were different from those at present demanded for their advantageous cultivation.*

---

* Probably no cultivated vegetable affords so good an opportunity of studying the laws of acclimation of plants as maize or Indian corn. Maize is grown from the tropics to at least lat. 47° in Northeastern America, and farther

Even if we suppose an identity of species, of race, and of habit to be established between a given ancient and modern plant, the negative fact that the latter will not grow now where it flourished two thousand years ago does not in all cases prove a change of climate. The same result might follow from the exhaustion of the soil,* or from a change in the quantity of moisture it habitually contains. After a district of country has

---

north in Europe. Every two or three degrees of latitude brings you to a new variety, with new climatic adaptations, and the capacity of the plant to accommodate itself to new conditions of temperature and season seems almost unlimited.

Many persons now living remember that, when the common tomato was first introduced into Northern New England, it often failed to ripen; but, in the course of a very few years, it completely adapted itself to the climate, and now not only matures both its fruit and its seeds with as much certainty as any cultivated vegetable, but regularly propagates itself by self-sown seed. Meteorological observations, however, do not show any amelioration of the summer climate in those States within that period.

It may be said that these cases—and indeed all cases of a supposed acclimation consisting in physiological changes—are instances of the origination of new varieties by natural selection, the hardier maize, tomato, and other vegetables of the North, being the progeny of seeds of individuals endowed, exceptionally, with greater power of resisting cold than belongs in general to the species which produced them. But, so far as the evidence of change of climate, from a difference in vegetable growth, is concerned, it is immaterial whether we adopt this view or maintain the older and more familiar doctrine of a local modification of character in the plants in question.

Maize and the tomato, if not new to human use, have not been long known to civilization, and were, very probably, reclaimed and domesticated at a much more recent period than the plants which form the great staples of agricultural husbandry in Europe and Asia. Is the great power of accommodation to climate possessed by them due to this circumstance? There is some reason to suppose that the character of maize has been sensibly changed by cultivation in South America; for, according to Tschudi, the ears of this grain found in old Peruvian tombs belong to varieties not now known in Peru.—*Travels in Peru*, chap. vii. See important observations in SCHÜBELER, *Die Pflanzenwelt Norwegens* (*Allgemeiner Theil*), Christiania, 1873, 77 and following pp.

* The cultivation of madder is said to have been introduced into Europe by an Oriental in the year 1765, and it was first planted in the neighborhood of Avignon. Of course, it has been grown in that district for less than a century; but upon soils where it has been a frequent crop, it is already losing

been completely or even partially cleared of its forest growth, and brought under cultivation, the drying of the soil, under favorable circumstances, goes on for generations, perhaps for ages.* In other cases, from injudicious husbandry, or the diver-

---

much of its coloring properties.—LAVERGNE, *Économie Rurale de la France*, pp. 259-291.

I believe there is no doubt that the cultivation of madder in the vicinity of Avignon is of recent introduction; but it is certain that it was grown by the ancient Romans, and throughout nearly all Europe in the middle ages. The madder brought from Persia to France, may belong to a different species, or at least variety.

* In many parts of New England there are tracts, many square miles in extent and presenting all varieties of surface and exposure, which were partially cleared sixty or seventy years ago, and where little or no change in the proportion of cultivated ground, pasturage, and woodland has taken place since. In some cases, these tracts compose basins apparently scarcely at all exposed to any local influence in the way of percolation or infiltration of water towards or from neighboring valleys. But in such situations, apart from accidental disturbances, the ground is growing drier and drier from year to year, springs are still disappearing, and rivulets still diminishing in their summer supply of water. A probable explanation of this is to be found in the rapid drainage of the surface of cleared ground, which prevents the subterranean natural reservoirs, whether cavities or merely strata of bibulous earth, from filling up. How long this process is to last before an equilibrium is reached, none can say. It may be, for years; it may be, for centuries.

Livingstone states facts which strongly favor the supposition that a secular desiccation is still going on in central Africa, and there is reason to suspect that a like change is taking place in California. When the regions where the earth is growing drier were cleared of wood, or, indeed, whether forests ever grew there, we are unable to say, but the change appears to have been long in progress. A similar revolution appears to have occurred in Arabia Petræa. In many of the wadis, and particularly in the gorges between Wadi Feiran and Wadi Esh Sheikh, there are water-worn banks showing that, at no very remote period, the winter floods must have risen fifty feet in channels where the growth of acacias and tamarisks and the testimony of the Arabs concur to prove that they have not risen six feet within the memory or tradition of the present inhabitants. Recent travellers have discovered traces of extensive ancient cultivation, and of the former existence of large towns in the Tih desert, in localities where all agriculture is now impossible for want of water. Is this drought due to the destruction of ancient forests or to some other cause?

For important observations on supposed changes of climate in our Western sion or choking up of natural water-courses, it may become more highly charged with humidity. An increase or diminution of the moisture of a soil almost necessarily supposes an elevation or a depression of its winter or its summer heat, and of its extreme if not of its mean annual temperature, though such elevation or depression may be so slight as not sensibly to raise or lower the mercury in a thermometer exposed to the open air. Any of these causes, more or less humidity, or more or less warmth of soil, would affect the growth both of wild and of cultivated vegetation, and consequently, without any appreciable change in atmospheric temperature, precipitation, or evaporation, plants of a particular species might cease to be advantageously cultivated where they had once been easily reared.*

---

prairie region, from cultivation of the soil and the introduction of domestic cattle, see BRYANT'S valuable *Forest Trees*, 1871, chapter v., and HAYDEN, *Preliminary Report on Survey of Wyoming*, p. 455.

Some physicists believe that the waters of our earth are, from chemical or other less known causes, diminishing by entering into new inorganic combinations, and that this element will finally disappear from the globe.

* The soil of newly subdued countries is generally highly favorable to the growth of the fruits of the garden and the orchard, but usually becomes much less so in a very few years. Plums, of many varieties, were formerly grown, in great perfection and abundance, in many parts of New England where at present they can scarcely be reared at all; and the peach, which, a generation or two ago, succeeded admirably in the southern portion of the same States, has almost ceased to be cultivated there. The disappearance of these fruits is partly due to the ravages of insects, which have in later years attacked them; but this is evidently by no means the sole, or even the principal cause of their decay. In these cases, it is not to the exhaustion of the particular acres on which the fruit trees have grown that we are to ascribe their degeneracy, but to a general change in the condition of the soil or the air; for it is equally impossible to rear them successfully on absolutely new land in the neighborhood of grounds where, not long since, they bore the finest fruit.

I remember being told, many years ago, by intelligent early settlers of the State of Ohio, that the apple trees raised there from seed sown soon after the land was cleared, bore fruit in less than half the time required to bring to bearing those reared from seed sown when the ground had been twenty years under cultivation.

Uncertainty of Modern Meteorology.

We are very imperfectly acquainted with the present mean and extreme temperature, or the precipitation and the evaporation of any extensive region, even in countries most densely peopled and best supplied with instruments and observers. The progress of science is constantly detecting errors of method in older observations, and many laboriously constructed tables of meteorological phenomena are now thrown aside as fallacious, and therefore worse than useless, because some condition necessary to secure accuracy of result was neglected, in obtaining and recording the data on which they were founded.

To take a familiar instance: it is but recently that attention has been drawn to the great influence of slight differences in station upon the results of observations of temperature and precipitation. Two thermometers hung but a few hundred yards from each other differ not unfrequently five, sometimes even ten degrees in their readings;* and when we are told

---

Analogous changes occur slowly and almost imperceptibly even in spontaneous vegetation. In the peat mosses of Denmark, Scotch firs and other trees not now growing in the same localities, are found in abundance. Every generation of trees leaves the soil in a different state from that in which it found it; every tree that springs up in a group of trees of another species than its own, grows under different influences of light and shade and atmosphere from its predecessors. Hence the succession of crops, which occurs in all natural forests, seems to be due rather to changes of condition than of climate. See chapter iii., *post.*

* Tyndall, in a lecture on Radiation, expresses the opinion that from ten to fifteen per cent. of the heat radiated from the earth is absorbed by aqueous vapor within ten feet of the earth's surface.—*Fragments of Science*, 3d edition, London, 1871, p. 203.

Thermometers at most meteorological stations, when not suspended at points regulated by the mere personal convenience of the observer, are hung from 20 to 40 feet above the ground. In such positions they are less exposed to disturbance from the action of surrounding bodies than at a lower level, and their indications are consequently more uniform; but according to Tyndall's views they do not mark the temperature of the atmospheric stratum in which nearly all the vegetables useful to man, except forest trees, bud and blossom and ripen, and in which a vast majority of the ordinary operations of

There is one branch of research which is of the utmost importance in reference to these questions, but which, from the great difficulty of direct observation upon it, has been less successfully studied than almost any other problem of physical science. I refer to the proportions between precipitation, superficial drainage, absorption, and evaporation. Precise actual measurement of these quantities upon even a single acre of ground is impossible; and in all cabinet experiments on the subject, the conditions of the surface observed are so different from those which occur in nature, that we cannot safely reason from one case to the other. In nature, the inclination and exposure of the ground, the degree of freedom or obstruction of the flow of water over the surface, the composition and density of the soil, the presence or absence of perforations by worms and small burrowing quadrupeds—upon which the permeability of the ground by water and its power of absorbing and retaining or transmitting moisture depend—its temperature, the dryness or

---

whereas an easterly current comes from the west, and flows towards the east."—*Physical Geography*, p. 229.

There is no philological ground for this distinction, and it probably originated in a confusion of the terminations *-wardly* and *-erly*, both of which are modern. The root of the former ending implies the direction *to* or *to-wards* which motion is supposed. It corresponds to, and is probably allied with, the Latin *versus*. The termination *-erly* is a corruption or softening of *-ernly*, easterly for easternly, and many authors of the seventeenth century so write it. In Hakluyt (i., p. 2), *easterly* is applied to place, "*easterly* bounds," and means *eastern*. In a passage in Drayton, "*easterly* winds" must mean winds *from* the east; but the same author, in speaking of nations, uses *northerly* for *northern*. Hakewell says: "The sonne cannot goe more *southernely* from vs, nor come more *northernely* towards vs." Holland, in his translation of Pliny, referring to the moon, has: "When shee is *northerly*," and "shee is gone *southerly*." Richardson, to whom I am indebted for the above citations, quotes a passage from Dampier where *westerly* is applied to the wind, but the context does not determine the direction. The only example of the termination in *-wardly* given by this lexicographer is from Donne, where it means *towards* the west.

Shakspeare, in *Hamlet* (v., ii.), uses *northerly* wind for wind *from* the north. Milton does not employ either of these terminations, nor were they known to the Anglo-Saxons, who, however, had adjectives of direction in- *an* or *-en*, tion, or of tall meadow-grass; what given out again by surfaces so covered, or by bare ground of various textures and composition, under different conditions of atmospheric temperature, pressure, and humidity; or what is the amount of evaporation from water, ice, or snow, under the varying exposures to which, in actual nature, they are constantly subjected. If, then, we are so ignorant of all these climatic phenomena in the best-known regions inhabited by man, it is evident that we can rely little upon theoretical deductions applied to the former more natural state of the same regions—less still to such as are adopted with respect to distant, strange, and primitive countries.

Stability of Nature.

Nature, left undisturbed, so fashions her territory as to give it almost unchanging permanence of form, outline, and proportion, except when shattered by geologic convulsions; and in these comparatively rare cases of derangement, she sets herself at once to repair the superficial damage, and to restore, as nearly as practicable, the former aspect of her dominion. In new countries, the natural inclination of the ground, the self-formed slopes and levels, are generally such as best secure the stability of the soil. They have been graded and lowered or elevated by frost and chemical forces and gravitation and the flow of water and vegetable deposit and the action of the winds, until, by a general compensation of conflicting forces, a condition of equilibrium has been reached which, without the action of man, would remain, with little fluctuation, for countless ages.

We need not go far back to reach a period when, in all that portion of the North American continent which has been occupied by British colonization, the geographical elements very nearly balanced and compensated each other. At the commencement of the seventeenth century, the soil, with insignificant exceptions, was covered with forests; * and whenever the Indian, permanent change was produced by them. I refer to the action of beavers and of fallen trees in producing bogs,* and of smaller animals, insects, and birds, in destroying the woods.[*]

---

* I do not here speak of the vast prairie region of the Mississippi valley, which cannot properly be said ever to have been a field of British colonization;

---

* The English nomenclature of this geographical feature does not seem well settled. We have *bog*, *swamp*, *marsh*, *morass*, *moor*, *fen*, *turf-moss*, *peat-moss*, *quagmire*, all of which, though sometimes more or less accurately discriminated, are often used interchangeably, or are perhaps employed, each exclusively, in a particular district. In Sweden, where, especially in the Lappish provinces, this terr-aqueous formation is very extensive and important, the names of its different kinds are more specific in their application. The general designation of all soils permanently pervaded with water is *Kärr*. The elder Læstadius divides the *Kärr* into two genera: *Myror* (sing. *myra*), and *Mossar* (sing. *mosse*). "The former," he observes, "are grass-grown, and overflowed with water through almost the whole summer; the latter are covered with mosses and always moist, but very seldom overflowed." He enumerates the following species of *Myra*, the character of which will perhaps be sufficiently understood by the Latin terms into which he translates the vernacular names, for the benefit of strangers not altogether familiar with the language and the subject: 1. *Hömyror*, paludes graminosæ. 2. *Dy*, paludes profundæ. 3. *Flarkmyror*, or proper *kärr*, paludes limosæ. 4. *Fjälimyror*, paludes uliginosæ. 5. *Tufmyror*, paludes cæspitosæ. 6. *Rismyror*, paludes virgatæ. 7. *Starrängar*, prata irrigata, with their subdivisions, dry *starrängar* or *risängar*, wet *starrängar* and *fräkengropar*. 8. *Pölar*, lacunæ. 9. *Gölar*, fossæ inundatæ. The *Mossar*, paludes turfosæ, which are of great extent, have but two species: 1. *Torfmossar*, called also *Mossmyror* and *Snottermyror*, and, 2. *Björnmossar*.

The accumulations of stagnant or stagnating water originating in bogs are distinguished into *Träsk*, stagna, and *Tjernar* or *Tjärnar* (sing. *Tjern* or *Tjärn*), stagnatiles. *Träsk* are pools fed by bogs, or water emanating from them, and their bottoms are slimy; *Tjernar* are small *Träsk* situated within the limits of *Mossar*.—L. L. LÆSTADIUS, *om Möjligheten af Uppodlingar i Lappmarken*, pp. 23, 24.

Although the quantity of bog land in New England is less than in many other regions of equal area, yet there is a considerable extent of this formation in some of the Northeastern States. Dana (*Manual of Geology*, p. 614) states that the quantity of peat in Massachusetts is estimated at 120,000,000 cords, or nearly 569,000,000 cubic yards, but he does not give either the area or the depth of the deposits. In any event, however, bogs cover but a small percentage of the territory in any of the Northern States, while it is said that one tenth of the whole surface of Ireland is composed of bogs, and there are still extensive tracts of undrained marsh in England. The amount of this formation in Great Britain is estimated at 6,000,000 acres, with an average depth of twelve feet, which would yield 21,600,000 tons of air-dried peat.—ASBJÖRNSEN, *Tore og Toredrift*, Christiania, 1868, p. 6.

Bogs generally originate in the checking of watercourses by the falling of timber or of earth and rocks, or by artificial obstructions across their channels. If the impediment is sufficient to retain a permanent accumulation of water behind it, the trees whose roots are overflowed soon perish, and then by their fall increase the obstruction, and, of course, occasion a still wider spread of the stagnating stream. This process goes on until the water finds a new outlet, at a higher level, not liable

---

Peat beds have sometimes a thickness of ten or twelve yards, or even more. A depth of ten yards would give 48,000 cubic yards to the acre. The greatest quantity of firewood yielded by the forests of New England to the acre is 100 cords solid measure, or 474 cubic yards; but this comprises only the trunks and larger branches. If we add the small branches and twigs, it is possible that 600 cubic yards might, in some cases, be cut on an acre. This is only one eightieth part of the quantity of peat sometimes found on the same area. It is true that a yard of peat and a yard of wood are not the equivalents of each other, but the fuel on an acre of deep peat is worth much more than that on an acre of the best woodland. Besides this, wood is perishable, and the quantity on an acre cannot be increased beyond the amount just stated; peat is indestructible, and the beds are always growing. See *post*, Chap. IV. Cold favors the conversion of aquatic vegetables into peat. Asbjörnsen says some of the best peat he has met with is from a bog which is frozen for forty weeks in the year.

The Greeks and Romans were not acquainted with the employment of peat as fuel, but it appears from a curious passage which I have already cited from Pliny, *N. H.*, book xvi., chap. 1, that the inhabitants of the North Sea coast used what is called *kneaded turf* in his time. This is the finer and more thoroughly decomposed matter lying at the bottom of the peat, kneaded by the hands, formed into small blocks and dried. It is still prepared in precisely the same way by the poorer inhabitants of those shores.

But though the Low German tribes, including probably the Anglo-Saxons, have used peat as fuel from time immemorial, it appears not to have been known to the High Germans until a recent period. At least, I can find neither in Old nor in Middle High German lexicons and glossaries any word signifying peat. *Zurb* indeed is found in Graff as an Old High German word, but only in the sense of grass-turf, or greensward. Peat bogs of vast extent occur in many High German localities, but the former abundance of wood in the same regions rendered the use of peat unnecessary.

[*] See Chapter II., *post*.

tion both of new countries and of old. If the precipitation, whether great or small in amount, be equally distributed through the seasons, so that there are neither torrential rains nor parching droughts, and if, further, the general inclination of ground be moderate, so that the superficial waters are carried off without destructive rapidity of flow, and without sudden accumulation in the channels of natural drainage, there is little danger of the degradation of the soil in consequence of the removal of forest or other vegetable covering, and the natural face of the earth may be considered as virtually permanent. These conditions are well exemplified in Ireland, in a great part of England, in extensive districts in Germany and France, and, fortunately, in an immense proportion of the valley of the Mississippi and the basin of the great American lakes, as well as in many parts of the continents of South America and of Africa, and it is partly, though by no means entirely, owing to topographical and climatic causes that the blight, which has smitten the fairest and most fertile provinces of Imperial Rome, has spared Britannia, Germania, Pannonia, and Mœsia, the comparatively inhospitable homes of barbarous races, who, in the days of the Cæsars, were too little advanced in civilized life to possess either the power or the will to wage that war against the order of nature which seems, hitherto, an almost inseparable condition precedent of high social culture, and of great progress in fine and mechanical art.

Destructive changes are most frequent in countries of irregular and mountainous surface, and in climates where the precipitation is confined chiefly to a single season, and where, of course, the year is divided into a wet and a dry period, as is the case throughout a great part of the Ottoman empire, and, indeed, in a large proportion of the whole Mediterranean basin.

In mountainous countries various causes combine to expose the soil to constant dangers. The rain and snow usually fall in greater quantity, and with much inequality of distribution; the snow on the summits accumulates for many months in succession, and then is not unfrequently almost wholly dissolved in a single thaw, so that the entire precipitation of months is in a few hours hurried down the flanks of the mountains, and through the ravines that furrow them; the natural inclination of the surface promotes the swiftness of the gathering currents of diluvial rain and of melting snow, which soon acquire an almost irresistible force and power of removal and transportation; the soil itself is less compact and tenacious than that of the plains, and if the sheltering forest has been destroyed, it is confined by few of the threads and ligaments by which nature had bound it together, and attached it to the rocky groundwork. Hence every considerable shower lays bare its roods of rock, and the torrents sent down by the thaws of spring, and by occasional heavy discharges of the summer and autumnal rains, are seas of mud and rolling stones that sometimes lay waste and bury beneath them acres, and even miles, of pasture and field and vineyard.*

Destructiveness of Man.

Man has too long forgotten that the earth was given to him for usufruct alone, not for consumption, still less for profligate waste. Nature has provided against the absolute destruction of any of her elementary matter, the raw material of her works; the thunderbolt and the tornado, the most convulsive throes of even the volcano and the earthquake, being only phenomena of decomposition and recomposition. But she has left it within the power of man irreparably to derange the combinations of inorganic matter and of organic life, which through the night of æons she had been proportioning and balancing, to prepare the earth for his habitation, when in the fulness of time his Creator should call him forth to enter into its possession.

---

* The character of geological formation is an element of very great importance in determining the amount of erosion produced by running water, and, of course, in measuring the consequences of clearing off the forests. The soil of the French Alps yields very readily to the force of currents, and the declivities of the northern Apennines, as well as of many minor mountain ridges in Tuscany and other parts of Italy, are covered with earth which becomes itself almost a fluid when saturated with water. Hence the erosion of such surfaces is vastly greater than on many other mountains of equal steepness of inclination. The traveller who passes over the route between Bologna and Florence, and the Perugia and the Siena roads from the latter city to Rome, will have many opportunities of observing such localities.

Apart from the hostile influence of man, the organic and the inorganic world are, as I have remarked, bound together by such mutual relations and adaptations as secure, if not the absolute permanence and equilibrium of both, a long continuance of the established conditions of each at any given time and place, or at least, a very slow and gradual succession of changes in those conditions. But man is everywhere a disturbing agent. Wherever he plants his foot, the harmonies of nature are turned to discords. The proportions and accommodations which insured the stability of existing arrangements are overthrown. Indigenous vegetable and animal species are extirpated, and supplanted by others of foreign origin, spontaneous production is forbidden or restricted, and the face of the earth is either laid bare or covered with a new and reluctant growth of vegetable forms, and with alien tribes of animal life. These intentional changes and substitutions constitute, indeed, great revolutions; but vast as is their magnitude and importance, they are, as we shall see, insignificant in comparison with the contingent and unsought results which have flowed from them.

The fact that, of all organic beings, man alone is to be regarded as essentially a destructive power, and that he wields energies to resist which Nature—that nature whom all material life and all inorganic substance obey—is wholly impotent, tends to prove that, though living in physical nature, he is not of her, that he is of more exalted parentage, and belongs to a higher order of existences, than those which are born of her womb and live in blind submission to her dictates.

There are, indeed, brute destroyers, beasts and birds and insects of prey—all animal life feeds upon, and, of course, destroys other life,—but this destruction is balanced by compensations. It is, in fact, the very means by which the existence of one tribe of animals or of vegetables is secured against being smothered by the encroachments of another; and the reproductive powers of species, which serve as the food of others, are always proportioned to the demand they are destined to supply. Man pursues his victims with reckless destructiveness; and, while the sacrifice of life by the lower animals is limited by the cravings of appetite, he unsparingly persecutes, even to extirpation, thousands of organic forms which he cannot consume.*

---

* The terrible destructiveness of man is remarkably exemplified in the chase of large mammalia and birds for single products, attended with the entire waste of enormous quantities of flesh, and of other parts of the animal which are capable of valuable uses. The wild cattle of South America are slaughtered by millions for their hides and horns; the buffalo of North America for his skin or his tongue; the elephant, the walrus, and the narwhal for their tusks; the cetacea, and some other marine animals, for their whalebone and oil; the ostrich and other large birds, for their plumage. Within a few years, sheep have been killed in New England, by whole flocks, for their pelts and suet alone, the flesh being thrown away; and it is even said that the bodies of the same quadrupeds have been used in Australia as fuel for limekilns. What a vast amount of human nutriment, of bone, and of other animal products valuable in the arts, is thus recklessly squandered! In nearly all these cases, the part which constitutes the motive for this wholesale destruction, and is alone saved, is essentially of insignificant value as compared with what is thrown away. The horns and hide of an ox are not economically worth a tenth part as much as the entire carcass. During the present year, large quantities of Indian corn have been used as domestic fuel, and even for burning lime, in Iowa and other Western States. Corn at from fifteen to eighteen cents per bushel is found cheaper than wood at from five to seven dollars per cord, or coal at six or seven dollars per ton.—*Rep. Agric. Dept.*, Nov. and Dec., 1872, p. 487.

One of the greatest benefits to be expected from the improvements of civilization is, that increased facilities of communication will render it possible to transport to places of consumption much valuable material that is now wasted because the price at the nearest market will not pay freight. The cattle slaughtered in South America for their hides would feed millions of the starving population of the Old World, if their flesh could be economically preserved and transported across the ocean. This, indeed, is already done, but on a scale which, though absolutely considerable, is relatively insignificant. South America sends to Europe a certain quantity of nutriment in the form of meat extracts, Liebig's and others; and preserved flesh from Australia is beginning to figure in the English market.

We are beginning to learn a better economy in dealing with the inorganic

The earth was not, in its natural condition, completely adapted to the use of man, but only to the sustenance of wild animals and wild vegetation. These live, multiply their kind in just proportion, and attain their perfect measure of strength and beauty, without producing or requiring any important change in the natural arrangements of surface, or in each other's spontaneous tendencies, except such mutual repression of excessive increase as may prevent the extirpation of one species by the encroachments of another. In short, without man, lower animal and spontaneous vegetable life would have been practically constant in type, distribution, and proportion, and the physical geography of the earth would have remained undisturbed for indefinite periods, and been subject to revolution

---

world. The utilization—or, as the Germans more happily call it, the Verwerthung, the *beworthing*—of waste from metallurgical, chemical, and manufacturing establishments, is among the most important results of the application of science to industrial purposes. The incidental products from the laboratories of manufacturing chemists often become more valuable than those for the preparation of which they were erected. The slags from silver refineries, and even from smelting houses of the coarser metals, have not unfrequently yielded to a second operator a better return than the first had derived from dealing with the natural ore; and the saving of lead carried off in the smoke of furnaces has, of itself, given a large profit on the capital invested in the works. According to *Ure's Dictionary of Arts*, see vol. ii., p. 832, an English miner has constructed flues five miles in length for the condensation of the smoke from his lead-works, and makes thereby an annual saving of metal to the value of ten thousand pounds sterling. A few years ago, an officer of an American mint was charged with embezzling gold committed to him for coinage. He insisted, in his defence, that much of the metal was volatilized and lost in refining and melting, and upon scraping the chimneys of the melting furnaces and the roofs of the adjacent houses, gold enough was found in the soot to account for no small part of the deficiency.

The substitution of expensive machinery for manual labor, even in agriculture—not to speak of older and more familiar applications—besides being highly remunerative, has better secured the harvests, and it is computed that the 230,000 threshing machines used in the United States in 1870 obtained five per cent. more grain from the sheaves which passed through them than could have been secured by the use of the flail.

The cotton growing States in America produce annually nearly three million tons of cotton seed. This, until very recently, has been thrown away as a only from slow development, from possible, unknown cosmical causes, or from geological action.

But man, the domestic animals that serve him, the field and garden plants the products of which supply him with food and clothing, cannot subsist and rise to the full development of their higher properties, unless brute and unconscious nature be effectually combated, and, in a great degree, vanquished by human art. Hence, a certain measure of transformation of terrestrial surface, of suppression of natural, and stimulation of artificially modified productivity becomes necessary. This measure man has unfortunately exceeded. He has felled the forests whose network of fibrous roots bound the mould to the rocky skeleton of the earth; but had he allowed here and there a belt of woodland to reproduce itself by spontaneous propagation, most of the mischiefs which his reckless destruction of the natural protection of the soil has occasioned would have been

---

useless incumbrance, but it is now valued at ten or twelve dollars per ton for the cotton fibre which adheres to it, for the oil extracted from it, and for the feed which the refuse furnishes to cattle. The oil—which may be described as neutral—is used very largely for mixing with other oils, many of which bear a large proportion of it without injury to their special properties.

There are still, however, cases of enormous waste in many mineral and mechanical industries. Thus, while in many European countries common salt is a government monopoly, and consequently so dear that the poor do not use as much of it as health requires, in others, as in Transylvania, where it is quarried like stone, the large blocks only are saved, the fragments, to the amount of millions of hundred weights, being thrown away.—BONAR, *Transylvania*, p. 455, 6.

One of the most interesting and important branches of economy at the present day is the recovery of agents such as ammonia and others which had been utilized in chemical manufactures, and re-employing them indefinitely afterwards in repeating the same process.

Among the supplemental exhibitions which will be formed in connection with the Vienna Universal Exhibition is to be one showing what steps have been taken since 1851 (the date of the first London Exhibition) in the utilization of substances previously regarded as waste. On the one hand will be shown the waste products in all the industrial processes included in the forthcoming Exhibition; on the other hand, the useful products which have been obtained from such wastes since 1851. This is intended to serve as an incentive to further researches in the same important direction.

averted. He has broken up the mountain reservoirs, the percolation of whose waters through unseen channels supplied the fountains that refreshed his cattle and fertilized his fields; but he has neglected to maintain the cisterns and the canals of irrigation which a wise antiquity had constructed to neutralize the consequences of its own imprudence. While he has torn the thin glebe which confined the light earth of extensive plains, and has destroyed the fringe of semi-aquatic plants which skirted the coast and checked the drifting of the sea sand, he has failed to prevent the spreading of the dunes by clothing them with artificially propagated vegetation. He has ruthlessly warred on all the tribes of animated nature whose spoil he could convert to his own uses, and he has not protected the birds which prey on the insects most destructive to his own harvests.

Purely untutored humanity, it is true, interferes comparatively little with the arrangements of nature,* and the destruc-

---

* It is an interesting and not hitherto sufficiently noticed fact, that the domestication of the organic world, so far as it has yet been achieved, belongs, not indeed to the savage state, but to the earliest dawn of civilization, the conquest of inorganic nature almost as exclusively to the most advanced stages of artificial culture. Civilization has added little to the number of vegetable or animal species grown in our fields or bred in our folds—the cranberry and the wild grape being almost the only plants which the Anglo-American has reclaimed out of our vast native flora and added to his harvests—while, on the contrary, the subjugation of the inorganic forces, and the consequent extension of man's sway over, not the annual products of the earth only, but her substance and her springs of action, is almost entirely the work of highly refined and cultivated ages. The employment of the elasticity of wood and of horn, as a projectile power in the bow, is nearly universal among the rudest savages. The application of compressed air to the same purpose, in the blowpipe, is more restricted, and the use of the mechanical powers, the inclined plane, the wheel and axle, and even the wedge and lever, seems almost unknown except to civilized man. I have myself seen European peasants to whom one of the simplest applications of this latter power was a revelation.

It is familiarly known to all who have occupied themselves with the psychology and habits of the ruder races, and of persons with imperfectly developed intellects in civilized life, that although these humble tribes and individuals sacrifice, without scruple, the lives of the lower animals to the gratification of their appetites and the supply of their other physical wants, tive agency of man becomes more and more energetic and unsparing as he advances in civilization, until the impoverishment, with which his exhaustion of the natural resources of the soil is threatening him, at last awakens him to the necessity of preserving what is left, if not of restoring what has been wantonly wasted. The wandering savage grows no cultivated

---

yet they nevertheless seem to cherish with brutes, and even with vegetable life, sympathies which are much more feebly felt by civilized men. The popular traditions of the simpler peoples recognize a certain community of nature between man, brute animals, and even plants; and this serves to explain why the apologue or fable, which ascribes the power of speech and the faculty of reason to birds, quadrupeds, insects, flowers, and trees, is one of the earliest forms of literary composition.

In almost every wild tribe, some particular quadruped or bird, though persecuted as a destroyer of other animals more useful to man, or hunted for food, is regarded with peculiar respect, one might almost say, affection. Some of the North American aboriginal nations celebrate a propitiatory feast to the manes of the intended victim before they commence a bear hunt; and the Norwegian peasantry have not only retained an old proverb which ascribes to the same animal "*ti Mænds Styrke og tolv Mænds Vid*," ten men's strength and twelve men's cunning, but they still pay to him something of the reverence with which ancient superstition invested him. The student of Icelandic literature will find in the saga of *Finnbogi hinn rami* a curious illustration of this feeling, in an account of a dialogue between a Norwegian bear and an Icelandic champion—dumb show on the part of Bruin, and chivalric words on that of Finnbogi—followed by a duel, in which the latter, who had thrown away his arms and armor in order that the combatants might meet on equal terms, was victorious. See also FRIIS, *Lappisk Mythologi*, Christiania, 1871, § 37, and the earlier authors there cited. Drummond Hay's very interesting work on Morocco contains many amusing notices of a similar feeling entertained by the Moors towards the redoubtable enemy of their flocks—the lion.

This sympathy helps us to understand how it is that most if not all the domestic animals—if indeed they ever existed in a wild state—were appropriated, reclaimed and trained before men had been gathered into organized and fixed communities, that almost every known esculent plant had acquired substantially its present artificial character, and that the properties of nearly all vegetable drugs and poisons were known at the remotest period to which historical records reach. Did nature bestow upon primitive man some instinct akin to that by which she has been supposed to teach the brute to select the nutritious and to reject the noxious vegetables indiscriminately mixed in forest and pasture?

This instinct, it must be admitted, is far from infallible, and, as has been vegetable, fells no forest, and extirpates no useful plant, no noxious weed. If his skill in the chase enables him to entrap numbers of the animals on which he feeds, he compensates this loss by destroying also the lion, the tiger, the wolf, the otter, the seal, and the eagle, thus indirectly protecting the feebler quadrupeds and fish and fowls, which would otherwise become

---

hundreds of times remarked by naturalists, it is in many cases not an original faculty but an acquired and transmitted habit. It is a fact familiar to persons engaged in sheep husbandry in New England—and I have seen it confirmed by personal observation—that sheep bred where the common laurel, as it is called, *Kalmia angustifolia*, abounds, almost always avoid browsing upon the leaves of that plant, while those brought from districts where laurel is unknown, and turned into pastures where it grows, very often feed upon it and are poisoned by it. A curious acquired and hereditary instinct, of a different character, may not improperly be noticed here. I refer to that by which horses bred in provinces where quicksands are common avoid their dangers or extricate themselves from them. See BRÉMONTIER, *Mémoire sur les Dunes*, *Annales des Ponts et Chaussées*, 1833: *premier sémestre*, pp. 155–157.

It is commonly said in New England, and I believe with reason, that the crows of this generation are wiser than their ancestors. Scarecrows which were effectual fifty years ago are no longer respected by the plunderers of the cornfield, and new terrors must from time to time be invented for its protection.

Schroeder van der Kolk, in *Het Verschil tusschen den Psychischen Aanleg van het Dier en van den Mensch*, cites many interesting facts respecting instincts lost, or newly developed and become hereditary, in the lower animals, and he quotes Aristotle and Pliny as evidence that the common quadrupeds and fowls of our fields and our poultry yards were much less perfectly domesticated in their times than long, long ages of servitude have now made them.

Among other instances of obliterated instincts, this author states that in Holland, where, for centuries, the young of the cow has been usually taken from the dam at birth and fed by hand, calves, even if left with the mother, make no attempt to suck; while in England, where calves are not weaned until several weeks old, they resort to the udder as naturally as the young of wild quadrupeds.—*Ziel en Ligchaam*, p. 128, *n.*

Perhaps the half-wild character ascribed by P. Læstadius and other Swedish writers to the reindeer of Lapland, may be in some degree due to the comparative shortness of the period during which he has been partially tamed. The domestic swine bred in the woods of Hungary and the buffalo of Southern Italy are so wild and savage as to be very dangerous to all but their keepers. The former have relapsed into their original condition, the latter, perhaps, have never been fully reclaimed from it.

the booty of beasts and birds of prey. But with stationary life, or at latest with the pastoral state, man at once commences an almost indiscriminate warfare upon all the forms of animal and vegetable existence around him, and as he advances in civilization, he gradually eradicates or transforms every spontaneous product of the soil he occupies.*

Human and Brute Action Compared.

It is maintained by authorities as high as any known to modern science, that the action of man upon nature, though greater in *degree*, does not differ in *kind* from that of wild animals. It is perhaps impossible to establish a radical distinction *in genere* between the two classes of effects, but there is an essential difference between the motive of action which calls out the energies of civilized mañ and the mere appetite which controls the life of the beast. The action of man, indeed, is frequently followed by unforeseen and undesired results, yet it is nevertheless guided by a self-conscious will aiming as often at secondary and remote as at immediate objects. The wild animal, on the other hand, acts instinctively, and, so far as we are able to perceive, always with a view to single and direct purposes. The backwoodsman and the beaver alike fell trees; the man that he may convert the forest into an olive grove that will mature its fruit only for a succeeding generation, the beaver that he may feed upon the bark of the trees or use them in the construction of his habitation. The action of brutes upon the material world is slow and gradual, and usually limited, in any given case, to a narrow extent of territory. Nature is allowed time and opportunity to set her restorative powers at work, and the destructive animal has hardly retired from the field of his ravages before nature has repaired the damages occasioned by his operations. In fact, he is expelled from the scene by the very efforts which she makes for the restoration of her dominion. Man, on the contrary, extends his action over vast spaces, his revolutions are swift and radical, and his devastations are, for an almost incalculable time after he has withdrawn the arm that gave the blow, irreparable.

---

* The difference between the relations of savage life, and of incipient civilization, to nature, is well seen in that part of the valley of the Mississippi which was once occupied by the mound builders and afterwards by the far less developed Indian tribes. When the tillers of the fields, which must have been cultivated to sustain the large population that once inhabited those regions, perished, or were driven out, the soil fell back to the normal forest state, and the savages who succeeded the more advanced race interfered very little, if at all, with the ordinary course of spontaneous nature.

The form of geographical surface, and very probably the climate of a given country, depend much on the character of the vegetable life belonging to it. Man has, by domestication, greatly changed the habits and properties of the plants he rears; he has, by voluntary selection, immensely modified the forms and qualities of the animated creatures that serve him; and he has, at the same time, completely rooted out many forms of animal if not of vegetable being.* What is there, in the influence of brute life, that corresponds to this? We have no reason to believe that, in that portion of the American continent which, though peopled by many tribes of quadruped and fowl, remained uninhabited by man or only thinly occupied by purely savage tribes, any sensible geographical change had occurred within twenty centuries before the epoch of discovery and colonization, while, during the same period, man had changed millions of square miles, in the fairest and most fertile regions of the Old World, into the barrenest deserts.

---

* Whatever may be thought of the modification of organic species by natural selection, there is certainly no evidence that animals have exerted upon any form of life an influence analogous to that of domestication upon plants, quadrupeds, and birds reared artificially by man; and this is as true of unforeseen as of purposely effected improvements accomplished by voluntary selection of breeding animals.

It is true that nature employs birds and quadrupeds for the dissemination of vegetable and even of animal species. But when the bird drops the seed of a fruit it has swallowed, and when the sheep transports in its fleece the seed-vessel of a burdock from the plain to the mountain, its action is purely mechanical and unconscious, and does not differ from that of the wind in producing the same effect.

The ravages committed by man subvert the relations and destroy the balance which nature had established between her organized and her inorganic creations, and she avenges herself upon the intruder, by letting loose upon her defaced provinces destructive energies hitherto kept in check by organic forces destined to be his best auxiliaries, but which he has unwisely dispersed and driven from the field of action. When the forest is gone, the great reservoir of moisture stored up in its vegetable mould is evaporated, and returns only in deluges of rain to wash away the parched dust into which that mould has been converted. The well-wooded and humid hills are turned to ridges of dry rock, which encumbers the low grounds and chokes the watercourses with its débris, and—except in countries favored with an equable distribution of rain through the seasons, and a moderate and regular inclination of surface—the whole earth, unless rescued by human art from the physical degradation to which it tends, becomes an assemblage of bald mountains, of barren, turfless hills, and of swampy and malarious plains. There are parts of Asia Minor, of Northern Africa, of Greece, and even of Alpine Europe, where the operation of causes set in action by man has brought the face of the earth to a desolation almost as complete as that of the moon; and though, within that brief space of time which we call "the historical period," they are known to have been covered with luxuriant woods, verdant pastures, and fertile meadows, they are now too far deteriorated to be reclaimable by man, nor can they become again fitted for human use, except through great geological changes, or other mysterious influences or agencies of which we have no present knowledge, and over which we have no prospective control. The earth is fast becoming an unfit home for its noblest inhabitant, and another era of equal human crime and human improvidence, and of like duration with that through which traces of that crime and that improvidence extend, would reduce it to such a condition of impoverished productiveness, of shattered surface, of climatic excess, as to threaten the depravation, barbarism, and perhaps even extinction of the species.*

Physical Improvement.

True, there is a partial reverse to this picture. On narrow theatres, new forests have been planted; inundations of flowing streams restrained by heavy walls of masonry and other constructions; torrents compelled to aid, by depositing the slime with which they are charged, in filling up lowlands, and raising the level of morasses which their own overflows had created; ground submerged by the encroachments of the ocean, or exposed to be covered by its tides, has been rescued from its dominion by diking; swamps and even lakes have been drained, and their beds brought within the domain of agricultural industry; drifting coast dunes have been checked and made productive by plantation; seas and inland waters have been repeopled with fish, and even the sands of the Sahara have been fertilized by artesian fountains. These achievements are more glorious than the proudest triumphs of war, but, thus far, they give but faint hope that we shall yet make full atonement for our spendthrift waste of the bounties of nature.†

---

* ——"And it may be remarked that, as the world has passed through these several stages of strife to produce a Christendom, so by relaxing in the enterprises it has learnt, does it tend downwards, through inverted steps, to wildness and the waste again. Let a people give up their contest with moral evil; disregard the injustice, the ignorance, the greediness, that may prevail among them, and part more and more with the Christian element of their civilization; and in declining this battle with sin, they will inevitably get embroiled with men. Threats of war and revolution punish their unfaithfulness; and if then, instead of retracing their steps, they yield again, and are driven before the storm, the very arts they had created, the structures they had raised, the usages they had established, are swept away; 'in that very day their thoughts perish.' The portion they had reclaimed from the young earth's ruggedness is lost; and failing to stand fast against man, they finally get embroiled with nature, and are thrust down beneath her ever-living hand."
—MARTINEAU'S *Sermon*, "*The Good Soldier of Jesus Christ.*"

† The wonderful success which has attended the measures for subduing torrents and preventing inundations employed in Southern France since 1865,

Limits of Human Power.

It is, on the one hand, rash and unphilosophical to attempt to set limits to the ultimate power of man over inorganic nature, and it is unprofitable, on the other, to speculate on what may be accomplished by the discovery of now unknown and unimagined natural forces, or even by the invention of new arts and new processes. But since we have seen aerostation, the motive power of elastic vapors, the wonders of modern telegraphy, the destructive explosiveness of gunpowder, of nitro-glycerine, and even of a substance so harmless, unresisting, and inert as cotton, there is little in the way of mechanical achievement which seems hopelessly impossible, and it is hard to restrain the imagination from wandering forward a couple of generations to an epoch when our descendants shall have advanced as far beyond us in physical conquest, as we have marched beyond the trophies erected by our grandfathers. There are, nevertheless, in actual practice, limits to the efficiency of the forces which we are now able to bring into the field, and we must admit that, for the present, the agencies known to man and controlled by him are inadequate to the reducing of great Alpine precipices to such slopes as would enable them to support a vegetable clothing, or to the covering of large extents of denuded rock with earth, and planting upon them a forest growth. Yet among the mysteries which science is hereafter to reveal, there may be still undiscovered methods of accomplishing even grander wonders than these. Mechanical philosophers have suggested the possibility of accumulating and treasuring up for human use some of the greater natural forces, which the action of the elements puts forth with such astonishing energy. Could we gather, and bind, and make subservient to our control, the power which a West Indian hurricane exerts through a small area in

---

and described in Chapter III., *post*, ought to be here noticed as a splendid and most encouraging example of well-directed effort in the way of physical restoration.

one continuous blast, or the momentum expended by the waves, in a tempestuous winter, upon the breakwater at Cherbourg,* or the lifting power of the tide, for a month, at the head of the Bay of Fundy, or the pressure of a square mile of sea water at the depth of five thousand fathoms, or a moment of the might of an earthquake or a volcano, our age—which moves no mountains and casts them into the sea by faith alone—might hope to scarp the rugged walls of the Alps and Pyrenees and Mount Taurus, robe them once more in a vegetation as rich as that of their pristine woods, and turn their wasting torrents into refreshing streams.†

Could this old world, which man has overthrown, be rebuild-

---

* In heavy storms, the force of the waves as they strike against a sea-wall is from one and a half to two tons to the square foot, and Stevenson, in one instance at Skerryvore and in another at the Bell Rock lighthouse, found this force equal to nearly three tons per foot.

The seaward front of the breakwater at Cherbourg exposes a surface of about 2,500,000 square feet. In rough weather the waves beat against this whole face, though at the depth of twenty-two yards, which is the height of the breakwater, they exert a very much less violent motive force than at and near the surface of the sea, because this force diminishes in geometrical, as the distance below the surface increases in arithmetical, proportion. The shock of the waves is received several thousand times in the course of twenty-four hours, and hence the sum of impulse which the breakwater resists in one stormy day amounts to many thousands of millions of tons. The breakwater is entirely an artificial construction. If then man could accumulate and control the forces which he is able effectually to resist, he might be said to be, physically speaking, omnipotent.

† Some well-known experiments show that it is quite possible to accumulate the solar heat by a simple apparatus, and thus to obtain a temperature which might be economically important even in the climate of Switzerland. Saussure, by receiving the sun's rays in a nest of boxes blackened within and covered with glass, raised a thermometer enclosed in the inner box to the boiling point; and under the more powerful sun of the Cape of Good Hope, Sir John Herschel cooked the materials for a family dinner by a similar process, using, however, but a single box, surrounded with dry sand and covered with two glasses. Why should not so easy a method of economizing fuel be resorted to in Italy, in Spain, and even in more northerly climates?

The unfortunate John Davidson records in his journal that he saved fuel in Morocco by exposing his teakettle to the sun on the roof of his house, where the water rose to the temperature of one hundred and forty degrees, and, of ed, could human cunning rescue its wasted hillsides and its deserted plains from solitude or mere nomade occupation, from barrenness, from nakedness, and from insalubrity, and restore the ancient fertility and healthfulness of the Etruscan sea coast, the Campagna and the Pontine marshes, of Calabria, of Sicily, of the Peloponnesus and insular and continental Greece, of Asia Minor, of the slopes of Lebanon and Hermon, of Palestine, of the Syrian desert, of Mesopotamia and the delta of the Euphrates, of the Cyrenaica, of Africa proper, Numidia, and Mauritania, the thronging millions of Europe might still find room on the Eastern continent, and the main current of emigration be turned towards the rising instead of the setting sun.

But changes like these must await not only great political and moral revolutions in the governments and peoples by whom those regions are now possessed, but, especially, a command of pecuniary and of mechanical means not at present enjoyed by those nations, and a more advanced and generally diffused knowledge of the processes by which the amelioration of soil and climate is possible than now anywhere exists. Until such circumstances shall conspire to favor the work of geographical regeneration, the countries I have mentioned, with here and there a local exception, will continue to sink into yet deeper desolation, and in the meantime the American continent, Southern Africa, Australia, New Zealand, and the smaller oceanic islands, will be almost the only theatres where man is engaged, on a great scale, in transforming the face of nature.

---

course, needed little fire to bring it to boil. But this was the direct and simple, not the concentrated or accumulated heat of the sun.

On the utilizing of the solar heat, simply as heat, see the work of MOUCHOT, *La Chaleur solaire et ses applications industrielles*. Paris, 1869.

The reciprocal convertibility of the natural forces has suggested the possibility of advantageously converting the heat of the sun into mechanical power. Ericsson calculates that in all latitudes between the equator and 45°, a hundred square feet of surface exposed to the solar rays develop continuously, for nine hours a day on an average, eight and one fifth horse-power.

I do not know that any attempts have been made to accumulate and store up, for use at pleasure, force derived from this powerful source.

Importance of Physical Conservation and Restoration.

Comparatively short as is the period through which the colonization of foreign lands by European emigrants extends, great and, it is to be feared, sometimes irreparable injury has already been done in the various processes by which man seeks to subjugate the virgin earth; and many provinces, first trodden by the *homo sapiens Europæ* within the last two centuries, begin to show signs of that melancholy dilapidation which is now driving so many of the peasantry of Europe from their native hearths. It is evidently a matter of great moment, not only to the population of the states where these symptoms are manifesting themselves, but to the general interests of humanity, that this decay should be arrested, and that the future operations of rural husbandry and of forest industry, in districts yet remaining substantially in their native condition, should be so conducted as to prevent the widespread mischiefs which have been elsewhere produced by thoughtless or wanton destruction of the natural safeguards of the soil. This can be done only by the diffusion of knowledge on this subject among the classes that, in earlier days, subdued and tilled ground in which they had no vested rights, but who, in our time, own their woods, their pastures, and their ploughlands as a perpetual possession for them and theirs, and have, therefore, a strong interest in the protection of their domain against deterioration.

Physical Restoration.

Many circumstances conspire to invest with great present interest the questions: how far man can permanently modify and ameliorate those physical conditions of terrestrial surface and climate on which his material welfare depends; how far he can compensate, arrest, or retard the deterioration which many of his agricultural and industrial processes tend to produce; and how far he can restore fertility and salubrity to soils which his follies or his crimes have made barren or pestilential. Among these circumstances, the most prominent, perhaps, is the necessity of providing new homes for a European population which is increasing more rapidly than its means of subsistence, new physical comforts for classes of the people that have now become too much enlightened and have imbibed too much culture to submit to a longer deprivation of a share in the material enjoyments which the privileged ranks have hitherto monopolized.

To supply new hives for the emigrant swarms, there are, first, the vast unoccupied prairies and forests of America, of Australia, and of many other great oceanic islands, the sparsely inhabited and still unexhausted soils of Southern and even Central Africa, and, finally, the impoverished and half-depopulated shores of the Mediterranean, and the interior of Asia Minor and the farther East. To furnish to those who shall remain after emigration shall have conveniently reduced the too dense population of many European states, those means of sensuous and of intellectual well-being which are styled "artificial wants" when demanded by the humble and the poor, but are admitted to be "necessaries" when claimed by the noble and the rich, the soil must be stimulated to its highest powers of production, and man's utmost ingenuity and energy must be tasked to renovate a nature drained, by his improvidence, of fountains which a wise economy would have made plenteous and perennial sources of beauty, health, and wealth.

In those yet virgin lands which the progress of modern discovery in both hemispheres has brought and is still bringing to the knowledge and control of civilized man, not much improvement of great physical conditions is to be looked for. The proportion of forest is indeed to be considerably reduced, superfluous waters to be drawn off, and routes of internal communication to be constructed; but the primitive geographical and climatic features of these countries ought to be, as far as possible, retained.

In reclaiming and reoccupying lands laid waste by human improvidence or malice, and abandoned by man, or occupied only by a nomade or thinly scattered population, the task of the pioneer settler is of a very different character. He is to become a co-worker with nature in the reconstruction of the damaged fabric which the negligence or the wantonness of former lodgers has rendered untenantable. He must aid her in reclothing the mountain slopes with forests and vegetable mould, thereby restoring the fountains which she provided to water them; in checking the devastating fury of torrents, and bringing back the surface drainage to its primitive narrow channels; and in drying deadly morasses by opening the natural sluices which have been choked up, and cutting new canals for drawing off their stagnant waters. He must thus, on the one hand, create new reservoirs, and, on the other, remove mischievous accumulations of moisture, thereby equalizing and regulating the sources of atmospheric humidity and of flowing water, both which are so essential to all vegetable growth, and, of course, to human and lower animal life.

I have remarked that the effects of human action on the forms of the earth's surface could not always be distinguished from those resulting from geological causes, and there is also much uncertainty in respect to the precise influence of the clearing and cultivating of the ground, and of other rural operations, upon climate. It is disputed whether either the mean or the extremes of temperature, the periods of the seasons, or the amount or distribution of precipitation and of evaporation, in any country whose annals are known, have undergone any change during the historical period. It is, indeed, as has been already observed, impossible to doubt that many of the operations of the pioneer settler *tend* to produce great modifications in atmospheric humidity, temperature, and electricity; but we are at present unable to determine how far one set of effects is neutralized by another, or compensated by unknown agencies. This question scientific research is inadequate to solve, for want of the necessary data; but well conducted observation, in regions now first brought under the occupation of man, combined with such historical evidence as still exists, may be expected at no distant period to throw much light on this subject.

Australia and New Zealand are, perhaps, the countries from which we have a right to expect the fullest elucidation of these difficult and disputable problems. Their colonization did not commence until the physical sciences had become matter of almost universal attention, and is, indeed, so recent that the memory of living men embraces the principal epochs of their history; the peculiarities of their fauna, their flora, and their geology are such as to have excited for them the liveliest interest of the votaries of natural science; their mines have given their people the necessary wealth for procuring the means of instrumental observation, and the leisure required for the pursuit of scientific research; and large tracts of virgin forest and natural meadow are rapidly passing under the control of civilized man. Here, then, exist greater facilities and stronger motives for the careful study of the topics in question than have ever been found combined in any other theatre of European colonization.

In North America, the change from the natural to the artificial condition of terrestrial surface began about the period when the most important instruments of meteorological observation were invented. The first settlers in the territory now constituting the United States and the British American provinces had other things to do than to tabulate barometrical and thermometrical readings, but there remain some interesting physical records from the early days of the colonies,* and there is still an immense extent of North American soil where the industry and the folly of man have as yet produced little appreciable change. Here, too, with the present increased facilities for scientific observation, the future effects, direct and contingent, of man's labors, can be measured, and such precautions taken in those rural processes which we call improvements, as to mitigate evils, perhaps, in some degree, inseparable from every attempt to control the action of natural laws.

---

* The Travels of Dr. Dwight, president of Yale College, which embody the results of his personal observations, and of his inquiries among the early settlers, in his vacation excursions in the Northern States of the American Union, though presenting few instrumental measurements or tabulated results, are of value for the powers of observation they exhibit, and for the sound common sense with which many natural phenomena, such for instance as the formation of the river meadows, called "intervales," in New England, are explained. They present a true and interesting picture of physical conditions, many of which have long ceased to exist in the theatre of his researches, and of which few other records are extant.

In order to arrive at safe conclusions, we must first obtain a more exact knowledge of the topography, and of the present superficial and climatic condition of countries where the natural surface is as yet more or less unbroken. This can only be accomplished by accurate surveys, and by a great multiplication of the points of meteorological registry,* already so numerous; and as, moreover, considerable changes in the proportion of forest and of cultivated land, or of dry and wholly or partially submerged surface, will often take place within brief periods, it is highly desirable that the attention of observers, in whose neighborhood the clearing of the soil, or the drainage of lakes and swamps, or other great works of rural improvement, are going on or meditated, should be especially drawn not only to revolutions in atmospheric temperature and precipitation, but to the more easily ascertained and perhaps more important local changes produced by these operations in the temperature and the hygrometric state of the superficial strata of the earth, and in its spontaneous vegetable and animal products.

---

* The general law of temperature is that it decreases as we ascend. But, in hilly regions, the law is reversed in cold, still weather, the cold air descending, by reason of its greater gravity, into the valleys. If there be wind enough, however, to produce a disturbance and intermixture of higher and lower atmospheric strata, this exception to the general law does not take place. These facts have long been familiar to the common people of Switzerland and of New England, but their importance has not been sufficiently taken into account in the discussion of meteorological observations. The descent of the cold air and the rise of the warm affect the relative temperatures of hills and valleys to a much greater extent than has been usually supposed. A gentleman well known to me kept a thermometrical record for nearly half a century, in a New England country town, at an elevation of at least 1,500 feet above the sea. During these years his thermometer never fell lower than 26°—Fahrenheit, while at the shire town of the county, situated in a basin one thousand feet lower, and only ten miles distant, as well as at other points in similar positions, the mercury froze several times in the same period.

The rapid extension of railroads, which now everywhere keep pace with, and sometimes even precede, the occupation of new soil for agricultural purposes, furnishes great facilities for enlarging our knowledge of the topography of the territory they traverse, because their cuttings reveal the composition and general structure of surface, and the inclination and elevation of their lines constitute known hypsometrical sections, which give numerous points of departure for the measurement of higher and lower stations, and of course for determining the relief and depression of surface, the slope of the beds of watercourses, and many other not less important questions.*

---

* Railroad surveys must be received with great caution where any motive exists for *cooking* them. Capitalists are shy of investments in roads with steep grades, and of course it is important to make a fair show of facilities in obtaining funds for new routes. Joint-stock companies have no souls; their managers, in general, no consciences. Cases can be cited where engineers and directors of railroads, with long grades above one hundred feet to the mile, have regularly sworn in their annual reports, for years in succession, that there were no grades upon their routes exceeding half that elevation. In fact, every person conversant with the history of these enterprises knows that in their public statements falsehood is the rule, truth the exception.

What I am about to remark is not exactly relevant to my subject; but it is hard to "get the floor" in the world's great debating society, and when a speaker who has anything to say once finds access to the public ear, he must make the most of his opportunity, without inquiring too nicely whether his observations are "in order." I shall harm no honest man by endeavoring, as I have often done elsewhere, to excite the attention of thinking and conscientious men to the dangers which threaten the great moral and even political interests of Christendom, from the unscrupulousness of the private associations that now control the monetary affairs, and regulate the transit of persons and property, in almost every civilized country. More than one American State is literally governed by unprincipled corporations, which not only defy the legislative power, but have, too often, corrupted even the administration of jus-

The geological, hydrographical, and topographical surveys, which almost every general and even local government of the civilized world is carrying on, are making yet more important contributions to our stock of geographical and general physical knowledge, and, within a comparatively short space, there will be an accumulation of well established constant and historical facts, from which we can safely reason upon all the relations of action and reaction between man and external nature.

But we are, even now, breaking up the floor and wainscoting and doors and window frames of our dwelling, for fuel to warm our bodies and to seethe our pottage, and the world cannot afford to wait till the slow and sure progress of exact science has taught it a better economy. Many practical lessons have been learned by the common observation of unschooled

---

tice. The tremendous power of these associations is due not merely to pecuniary corruption, but partly to an old legal superstition—fostered by the decision of the Supreme Court of the United States in the famous Dartmouth College case—in regard to the sacredness of corporate prerogatives. There is no good reason why private *rights* derived from God and the very constitution of society should be less respected than privileges granted by legislatures. It should never be forgotten that no *privilege* can be a *right*, and legislative bodies ought never to make a grant to a corporation, without express reservation of what many sound jurists now hold to be involved in the very nature of such grants, the power of revocation. Similar evils have become almost equally rife in England, and on the Continent; and I believe the decay of commercial morality, and of the sense of all higher obligations than those of a pecuniary nature, on both sides of the Atlantic, is to be ascribed more to the influence of joint-stock banks and manufacturing and railway companies, to the workings, in short, of what is called the principle of "associate action," than to any other one cause of demoralization.

The apophthegm, "the world is governed too much," though unhappily too truly spoken of many countries—and perhaps, in some aspects, true of all—has done much mischief whenever it has been too unconditionally accepted as a political axiom. The popular apprehension of being over-governed, and, I am afraid, more emphatically the fear of being over-taxed, has had much to do with the general abandonment of certain governmental duties by the ruling powers of most modern states. It is theoretically the duty of government to provide all those public facilities of intercommunication and commerce, which are essential to the prosperity of civilized commonwealths, but which individual means are inadequate to furnish, and for the due administration of men; and the teachings of simple experience, on topics where natural philosophy has scarcely yet spoken, are not to be despised.

In these humble pages, which do not in the least aspire to rank among scientific expositions of the laws of nature, I shall attempt to give the most important practical conclusions suggested by the history of man's efforts to replenish the earth and subdue it; and I shall aim to support those conclusions by such facts and illustrations only as address themselves to the understanding of every intelligent reader, and as are to be found recorded in works capable of profitable perusal, or at least consultation, by persons who have not enjoyed a special scientific training.

---

which individual guaranties are insufficient. Hence public roads, canals, railroads, postal communications, the circulating medium of exchange whether metallic or representative, armies, navies, being all matters in which the nation at large has a vastly deeper interest than any private association can have, ought legitimately to be constructed and provided only by that which is the visible personification and embodiment of the nation, namely, its legislative head. No doubt the organization and management of these institutions by government are liable, as are all things human, to great abuses. The multiplication of public placeholders, which they imply, is a serious evil. But the corruption thus engendered, foul as it is, does not strike so deep as the rottenness of private corporations; and official rank, position, and duty have, in practice, proved better securities for fidelity and pecuniary integrity in the conduct of the interests in question, than the suretyships of private corporate agents, whose bondsmen so often fail or abscond before their principal is detected.

Many theoretical statesmen have thought that voluntary associations for strictly pecuniary and industrial purposes, and for the construction and control of public works, might furnish, in democratic countries, a compensation for the small and doubtful advantages, and at the same time secure an exemption from the great and certain evils, of aristocratic institutions. The example of the American States shows that private corporations—whose rule of action is the interest of the association, not the conscience of the individual—though composed of ultra-democratic elements, may become most dangerous enemies to rational liberty, to the moral interests of the commonwealth, to the purity of legislation and of judicial action, and to the sacredness of private rights.

CHAPTER II.

TRANSFER, MODIFICATION, AND EXTIRPATION OF VEGETABLE AND OF ANIMAL SPECIES.

Modern geography takes account of organic life—Geographical importance of plants—Origin of domestic vegetables—Transfer of vegetable life—Objects of modern commerce—Foreign plants, how introduced—Vegetable power of accommodation—Agricultural products of the United States—Useful American plants grown in Europe—Extirpation of vegetables—Animal life as a geological and geographical agency—Origin and transfer of domestic quadrupeds—Extirpation of wild quadrupeds—Large marine animals relatively unimportant in geography—Introduction and breeding of fish—Destruction of fish—Geographical importance of birds—Introduction of birds—Destruction of birds—Utility and destruction of reptiles—Utility of insects and worms—Injury to the forest by insects—Introduction of insects—Destruction of insects—Minute organisms.

Modern Geography embraces Organic Life.

It was a narrow view of geography which confined that science to delineation of terrestrial surface and outline, and to description of the relative position and magnitude of land and water. In its improved form it embraces not only the globe itself and the atmosphere which bathes it, but the living things which vegetate or move upon it, the varied influences they exert upon each other, the reciprocal action and reaction between them and the earth they inhabit. Even if the end of geographical studies were only to obtain a knowledge of the external forms of the mineral and fluid masses which constitute the globe, it would still be necessary to take into account the element of life; for every plant, every animal, is a geographical agency, man a destructive, vegetables, and in some cases even wild beasts, restorative powers.

The rushing waters sweep down earth from the uplands; in the first moment of repose, vegetation seeks to reëstablish itself on the bared surface, and, by the slow deposit of its decaying products, to raise again the soil which the torrent had lowered. So important an element of reconstruction is this, that it has been seriously questioned whether, upon the whole, vegetation does not contribute as much to elevate, as the waters to depress, the level of the surface.

Whenever man has transported a plant from its native habitat to a new soil, he has introduced a new geographical force to act upon it, and this generally at the expense of some indigenous growth which the foreign vegetable has supplanted. The new and the old plants are rarely the equivalents of each other, and the substitution of an exotic for a native tree, shrub, or grass, increases or diminishes the relative importance of the vegetable element in the geography of the country to which it is removed. Further, man sows that he may reap. The products of agricultural industry are not suffered to rot upon the ground, and thus raise it by an annual stratum of new mould. They are gathered, transported to greater or less distances, and after they have served their uses in human economy, they enter, on the final decomposition of their elements, into new combinations, and are only in small proportion returned to the soil on which they grew. The roots of the grasses, and of many other cultivated plants, however, usually remain and decay in the earth, and contribute to raise its surface, though certainly not in the same degree as the forest.

The smaller vegetables which have taken the place of trees unquestionably perform many of the same functions. They radiate heat, they absorb gases, and exhale uncombined gases and watery vapor, and consequently act upon the chemical constitution and hygrometrical condition of the air, their roots penetrate the earth to greater depths than is commonly supposed, and form an inextricable labyrinth of filaments which bind the soil together and prevent its erosion by water. The broad-leaved annuals and perennials, too, shade the ground, and prevent the evaporation of moisture from its surface by wind and sun.* At a certain stage of growth, grass land is probably a more energetic evaporator and refrigerator than even the forest, but this powerful action is exerted, in its full intensity, for a comparatively short time only, while trees continue such functions, with unabated vigor, for many months in succession. Upon the whole, it seems quite certain, that no cultivated ground is as efficient in tempering climatic extremes, or in conservation of geographical surface and outline, as is the soil which nature herself has planted.

Origin of Domestic Plants.

One of the most important questions connected with our subject is: how far we are to regard our cereal grains, our esculent bulbs and roots, and the multiplied tree fruits of our gardens, as artificially modified and improved forms of wild, self-propagating vegetation. The narratives of botanical travellers have often announced the discovery of the original form and habitat of domesticated plants, and scientific journals have described the experiments by which the identity of particular wild and cultivated vegetables has been thought to be established. It is confidently affirmed that maize and the potato—which we must suppose to have been first cultivated at a much later period than the breadstuffs and most other esculent vegetables of Europe and the East—are found wild and self-propagating in Spanish America, though in forms not recognizable by the common observer as identical with the familiar corn and tuber of modern agriculture. It was lately asserted, upon what seemed very strong evidence, that the *Ægilops ovata*, a plant growing wild in Southern France, had been actually converted into common wheat; but, upon a repetition of the experiments, later observers have declared that the apparent change was only a case of temporary hybridation or fecundation by the pollen of true wheat, and that the grass alleged to be transformed into wheat could not be perpetuated as such from its own seed.

---

* It is impossible to say how far the abstraction of water from the earth by broad-leaved field and garden plants—such as maize, the gourd family, the cabbage, &c.—is compensated by the condensation of dew, which sometimes pours from them in a stream, by the exhalation of aqueous vapor from their leaves, which is directly absorbed by the ground, and by the shelter they afford the soil from sun and wind, thus preventing evaporation. American farmers often say that after the leaves of Indian corn are large enough to "shade the ground," there is little danger that the plants will suffer from drought; but it is probable that the comparative security of the fields from this evil is in part due to the fact that, at this period of growth, the roots penetrate down to a permanently humid stratum of soil, and draw from it the moisture they require. Stirring the ground between the rows of maize with a light harrow or cultivator, in very dry seasons, is often recommended as a preventive of injury by drought. It would seem, indeed, that loosening and turning over the surface earth might aggravate the evil by promoting the evaporation of the little remaining moisture; but the practice is founded partly on the belief that the hygroscopicity of the soil is increased by it to such a degree that it gains more by absorption than it loses by evaporation, and partly on the doctrine that to admit air to the rootlets, or at least to the earth near them, is to supply directly elements of vegetable growth.

The very great modifications which cultivated plants are constantly undergoing under our eyes, and the numerous varieties and races which spring up among them, certainly countenance the doctrine, that every domesticated vegetable, however dependent upon human care for growth and propagation in its present form, may have been really derived, by a long succession of changes, from some wild plant not now perhaps much resembling it.* But it is, in every case, a question of evidence.

---

* What is the possible limit of such changes, we do not know, but they may doubtless be carried vastly beyond what experience has yet shown to be practicable. Civilized man has experimented little on wild plants, and especially on forest trees. He has indeed improved the fruit, and developed new varieties, of the chestnut, by cultivation, and it is observed that our American forest-tree nuts and berries, such as the butternut and the wild mulberry, become larger and better flavored in a single generation by planting and training. (BRYANT, *Forest Trees*, 1871, pp. 99, 115.) Why should not the industry and ingenuity which have wrought such wonders in our horticulture produce analogous results when applied to the cultivation and amelioration of larger vegetables? Might not, for instance, the ivory nut, the fruit of the *Phytelephas*

The only satisfactory proof that a given wild plant is identical with a given garden or field vegetable, is the test of experiment, the actual growing of the one from the seed of the other, or the conversion of the one into the other by transplantation and change of conditions.* It is hardly contended that any of the cereals or other plants important as human aliment, or as objects of agricultural industry, exist and propagate themselves uncultivated in the same form and with the same properties as when sown and reared by human art.† In fact, the cases are rare where the identity of a wild with a domesticated plant is considered by the best authorities as conclusively established, and we are warranted in affirming of but few of the latter, as a historically known or experimentally

---

macrocarpa, possibly be so increased in size as to serve nearly all the purposes of animal ivory now becoming so scarce? Might not the various milk-producing trees become, by cultivation, a really important source of nutriment to the inhabitants of warm climates? In short, there is room to hope incalculable advantage from the exercise of human skill in the improvement of yet untamed forms of vegetable life.

* The poisonous wild parsnip of New England has been often asserted to be convertible into the common garden parsnip by cultivation, or rather to be the same vegetable growing under different conditions, and it is said to be deprived of its deleterious qualities simply by an increased luxuriance of growth in rich, tilled earth. Wild medicinal plants, so important in the rustic *materia medica* of New England—such as pennyroyal, for example—are generally much less aromatic and powerful when cultivated in gardens than when self-sown on meagre soils. On the other hand, the *cinchona*, lately introduced from South America into British India and carefully cultivated there, is found to be richer in quinine than the American tree.

† Some recent observations of Wetzstein are worthy of special notice. "The soil of the Haurân," he remarks, "produces, in its primitive condition, much wild rye, which is not known as a cultivated plant in Syria, and much wild barley and oats. These cereals precisely resemble the corresponding cultivated plants in leaf, ear, size, and height of straw, but their grains are sensibly flatter and poorer in flour."—*Reisebericht über Haurân und die Trachonen*, p. 40.

Some of the cereals are, to a certain extent, self-propagating in the soil and climate of California. "*Volunteer* crops are grown from the seed which falls out in harvesting. Barley has been known to volunteer five crops in succession."—Prayer-Frowd, *Six Months in California*, p. 139.

proved fact, that they ever did exist, or could exist, independently of man.[*]

Transfer of Vegetable Life.

It belongs to vegetable and animal geography, which are almost sciences of themselves, to point out in detail what man has done to change the distribution of plants and of animated life and to revolutionize the aspect of organic nature; but some of the more important facts bearing on the first branch of this subject may pertinently be introduced here. Most of the cereal grains, the pulse, the edible roots, the tree fruits, and other important forms of esculent vegetation grown in Europe and the United States are believed, and—if the testimony of Pliny and other ancient naturalists is to be depended upon—many of them are historically known, to have originated in the temperate climates of Asia. The agriculture of even so old a country as Egypt has been almost completely revolutionized by the introduction of foreign plants, within the historical period. "With the exception of wheat," says Hehn, "the Nile valley now yields only new products, cotton, rice, sugar, indigo, sorghum, dates," being all unknown to its most ancient rural husbandry.[*] The wine grape has been thought to be truly indigenous only in the regions bordering on the eastern end of the Black Sea, where it now, particularly on the banks of the Rion, the ancient Phasis, propagates itself spontaneously, and grows with unexampled luxuriance.[†] But some species of the vine seem native to Europe, and many varieties of grape have been too long known as common to every part of the United States to admit of the supposition that they were introduced by European colonists.*

---

[*] This remark is much less applicable to fruit trees than to garden vegetables and the cerealia. The wild orange of Florida, though once considered indigenous, is now generally thought by botanists to be descended from the European orange introduced by the early colonists. On the wild apple trees of Massachusetts see an interesting chapter in THOREAU, *Excursions.* The fig and the olive are found growing wild in every country where those trees are cultivated. The wild fig differs from the domesticated in its habits, its season of fructification, and its insect population, but is, I believe, not specifically distinguishable from the garden fig, though I do not know that it is reclaimable by cultivation. The wild olive, which is so abundant in the Tuscan Maremma, produces good fruit without further care, when thinned out and freed from the shade of other trees, and is particularly suited for grafting. See SALVAGNOLI, *Memorie sulle Maremme*, pp. 63–73. The olive is indigenous in Syria and in the Punjaub, and forms vast forests in the Himalayas at from 1,400 to 2,100 feet above the level of the sea.—CLEGHORN, *Memoir on the Timber procured from the Indus, etc.*, pp. 8–15.

FRAAS, *Klima und Pflanzenwelt in der Zeit*, pp. 35–38, gives, upon the authority of Link and other botanical writers, a list of the native habitats of most cereals and of many fruits, or at least of localities where these plants are said to be now found wild; but the data do not appear to rest, in general, upon very trustworthy evidence. Theoretically, there can be little doubt that all our cultivated plants are modified forms of spontaneous vegetation, though the connection is not historically shown, nor are we able to say that the originals of some domesticated vegetables may not be now extinct and unrepresented in the existing wild flora. See, on this subject, HUMBOLDT, *Ansichten der Natur*, i., pp. 208, 209.

The Adams of modern botany and zoölogy have been put to hard shifts in finding names for the multiplied organisms which the Creator has brought before them, "to see what they would call them;" and naturalists and philosophers have shown much moral courage in setting at naught the laws of philology in the coinage of uncouth words to express scientific ideas. It is much to be wished that some bold neologist would devise English technical equivalents for the German *verwildert*, run-wild, and *veredelt*, improved by cultivation.

---

[*] On these points see the learned work of HEHN, *Kultur. Pflanzen und Thiere in ihrem Uebergang aus Asien.* 1870. On the migration of plants generally, see LYELL, *Principles of Geology*, 10th ed., vol. ii., c.

[†] The vine-wood planks of the ancient great door of the cathedral at Ravenna, which measured thirteen feet in length by a foot and a quarter in width, are traditionally said to have been brought from the Black Sea, by way of Constantinople, about the eleventh or twelfth century. Vines of such dimensions are now very rarely found in any other part of the East, and, though I have taken some pains on the subject, I never found in Syria or in Turkey a vine stock exceeding six inches in diameter, bark excluded. Schulz, however, saw at Beitschin, near Ptolemais, a vine measuring eighteen inches in diameter. Strabo speaks of vine-stocks in Margiana (Khorasan) of such dimensions that two men, with outstretched arms, could scarcely embrace them. See STRABO, ed. Casaubon, pp. 73, 516, 826. Statues of vine wood are mentioned by ancient writers. Very large vine-stems are not common in Italy, but the vine-wood panels of the door of the chapter-hall of the church of St. John at Saluzzo are not less than ten inches in width, and I observed not long since, in a garden at Piè di Mulera, a vine stock with a circumference of thirty inches.

Objects of Modern Commerce.

It is an interesting fact that the commerce—or at least the maritime carrying trade—and the agricultural and mechanical industry of the world are, in very large proportion, dependent on vegetable and animal products little or not at all known to ancient Greek, Roman, and Jewish civilization. In many instances, the chief supply of these articles comes from countries to which they are probably indigenous, and where they are still almost exclusively grown; but in most cases, the plants or animals from which they are derived have been introduced by man into regions now remarkable for their successful cultivation, and that, too, in comparatively recent times, or, in other words, within two or three centuries.

Something of detail on this subject cannot, I think, fail to prove interesting. Pliny mentions about thirty or forty oils as known to the ancients, of which only olive, sesame, rape seed and walnut oil—for except in one or two doubtful passages I find in this author no notice of linseed oil—appear to have been used in such quantities as to have had any serious importance in the carrying trade. At the present time, the new oils, linseed oil, the oil of the whale and other large marine animals, petroleum—of which the total consumption of the world in 1871 is estimated at 6,000,000 barrels, the port of Philadelphia alone exporting 56,000,000 gallons in that year—palm-oil recently introduced into commerce, and now imported into England from the coast of Africa at the rate of forty or fifty thousand tuns a year, these alone undoubtedly give employment to more shipping than the whole commerce of Italy—with the exception of wheat—at the most flourishing period of the Roman empire.* England imports annually about 600,000 tons of sugar, 100,000 tons of jute, and about the same quantity of esparto, six million tons of cotton, of which the value of $30,000,000 is exported again in the form of manufactured goods—including, by a strange industrial revolution, a large amount of cotton yarn and cotton tissues sent to India and directly or indirectly paid for by raw cotton to be manufactured in England—30,000 tons of tobacco, from 100,000 to 350,000 tons of guano, hundreds of thousands of tons of tea, coffee, cacao, caoutchouc, gutta-percha and numerous other important articles of trade wholly unknown, as objects of commerce, to the ancient European world; and this immense importation is balanced by a corresponding amount of exportation, not consist-

---

* The Northmen who—as I think it has been indisputably established by Professor Rafn of Copenhagen—visited the coast of Massachusetts about the year 1000, found grapes growing there in profusion, and the wild vine still flourishes in great variety and abundance in the southeastern counties of that State. The townships in the vicinity of the Dighton rock, supposed by many—with whom, however, I am sorry I cannot agree—to bear a Scandinavian inscription, abound in wild vines. According to LAUDONNIÈRE, *Histoire Notable de la Floride*, reprint, Paris, 1853, p 5, the French navigators in 1562 found in that peninsula "wild vines which climb the trees and produce good grapes."

---

* A very few years since, the United States had more than six hundred large ships engaged in the whale fishery, and the number of American whalers, in spite of the introduction of many new sources of oils, still amounts to two hundred and fifty.

The city of Rome imported from Sicily, from Africa, and from the Levant, enormous quantities of grain for gratuitous distribution among the lower classes of the capital. The pecuniary value of the gems, the spices, the unguents, the perfumes, the cosmetics and the tissues, which came principally from the East, was great, but these articles were neither heavy nor bulky and their transportation required but a small amount of shipping. The marbles, the obelisks, the statuary and other objects of art plundered in conquered provinces by Roman generals and governors, the wild animals, such as elephants, rhinoceroses, hippopotami, camelopards and the larger beasts of prey imported for slaughter at the public games, and the prisoners captured in foreign wars and brought to Italy for sale as slaves or butchery as gladiators, furnished employment for much more tonnage than all the legitimate commerce of the empire, with the possible exception of wheat.

Independently of the direct testimony of Latin authors, the Greek statuary, the Egyptian obelisks, and the vast quantities of foreign marbles, granite, porphyry, basalt, and other stones used in sculpture and in architecture, which ing, however, by any means, exclusively of articles new to commerce.*

Foreign Plants, how Introduced.

Besides the vegetables I have mentioned, we know that many plants of smaller economical value have been the subjects of international exchange in very recent times. Busbequius, Austrian ambassador at Constantinople about the middle of the sixteenth century—whose letters contain one of the best accounts of Turkish life which have appeared down to the present day—brought home from the Ottoman capital the lilac and the tulip. The Belgian Clusius about the same time introduced from the East the horse chestnut, which has since wandered to America. The weeping willows of Europe and the United States are said to have sprung from a slip received

---

have been found in the remains of ancient Rome, show that the Imperial capital must have employed an immense amount of tonnage in the importation of heavy articles for which there could have been no return freight, unless in the way of military transportation. Some of the Egyptian obelisks at Rome weigh upwards of four hundred tons, and many of the red granite columns from the same country must have exceeded one hundred tons. Greek and African marbles were largely used not only for columns, entablatures, and solid walls, but for casing the exterior and veneering the interior of public and private buildings. Scaurus imported, for the scene alone of a temporary theatre designed to stand scarcely for a month, three hundred and sixty columns, which were disposed in three tiers, the lower range being forty-two feet in height.—See PLINY, *Nat. Hist.*, Lib. xxxvi.

Italy produced very little for export, and her importations, when not consisting of booty, were chiefly paid for in coin which was principally either the spoil of war or the fruit of official extortion.

* Many of these articles would undoubtedly have been made known to the Greeks and Romans and have figured in their commerce, but for the slowness and costliness of ancient navigation, which, in the seas familiar to them, was suspended for a full third of the year from the inability of their vessels to cope with winter weather. The present speed and economy of transportation have wrought and are still working strange commercial and industrial revolutions. Algeria now supplies Northern Germany with fresh cauliflowers, and in the early spring the market-gardeners of Naples find it more profitable to send their first fruits to St. Petersburg than to furnish them to Florence and Rome.

from Smyrna by the poet Pope, and planted by him in an English garden; Drouyn de l'Huys, in a discourse delivered before the French Société d'Acclimatation, in 1860, claims for Rabelais the introduction of the melon, the artichoke and the Alexandria pink into France; and the Portuguese declare that the progenitor of all the European and American oranges was an Oriental tree transplanted to Lisbon, and still living in the last generation.[*] The present favorite flowers of the parterres of Europe have been imported from America, Japan and other remote Oriental countries, within a century and a half, and, in fine, there are few vegetables of any agricultural importance, few ornamental trees or decorative plants, which are not now common to the three civilized continents.

The statistics of vegetable emigration exhibit numerical results quite surprising to those not familiar with the subject. The lonely island of St. Helena is described as producing, at the time of its discovery in the year 1501, about sixty vegetable species, including some three or four known to grow elsewhere also.[†] At the present time its flora numbers seven hundred and fifty species—a natural result of the position of the island as the half-way house on the great ocean highway between Europe and the East. Humboldt and Bonpland found, among the unquestionably indigenous plants of tropical America, monocotyledons only, all the dicotyledons of those extensive regions having been probably introduced after the colonization of the New World by Spain.

---

[*] The name *portogallo*, so generally applied to the orange in Italy, seems to favor this claim. The orange, however, was known in Europe before the discovery of the Cape of Good Hope, and, therefore, before the establishment of direct relations between Portugal and the East.—See AMARI, *Storia dei Musulmani in Sicilia*, vol. ii., p. 445.

The date-palms of eastern and southern Spain were certainly introduced by the Moors. Leo von Rozmital, who visited Barcelona in 1476, says that the date-tree grew in great abundance in the environs of that city and ripened its fruit well. It is now scarcely cultivated further north than Valencia. It is singular that Ritter in his very full monograph on the palm does not mention those of Spain.

On the introduction of *coniferæ* into England see an interesting article in the *Edinburgh Review* of October, 1864.

MÜLLER, *Das Buch der Pflanzenwelt*, p. 86, asserts that in 1802 the ancestor of all the mulberries in France, planted in 1500, was still standing in a garden in the village of Allan-Montélimart.

[†] It may be considered very highly probable, if not certain, that the undiscriminating herbalists of the sixteenth century must have overlooked many plants native to this island. An English botanist, in an hour's visit to Aden, discovered several species of plants on rocks always reported, even by scien-

The seven hundred new species which have found their way to St. Helena within three centuries and a half, were certainly not all, or even in the largest proportion, designedly planted there by human art, and if we were well acquainted with vegetable emigration, we should probably be able to show that man has intentionally transferred fewer plants than he has accidentally introduced into countries foreign to them. After the wheat, follow the tares that infest it. The weeds that grow among the cereal grains, the pests of the kitchen garden, are the same in America as in Europe.* The overturning of a wagon, or any of the thousand accidents which befall the emigrant in his journey across the Western plains, may scatter upon the ground the seeds he designed for his garden, and the herbs which fill so important a place in the rustic materia medica of the Eastern States, spring up along the prairie paths but just opened by the caravan of the settler.†

---

tific travellers, as absolutely barren. But after all, it appears to be well established that the original flora of St. Helena was extremely limited, though now counting hundreds of species.

* Some years ago I made a collection of weeds in the wheatfields of Upper Egypt, and another in the gardens on the Bosphorus. Nearly all the plants were identical with those which grow under the same conditions in New England. I do not remember to have seen in America the scarlet wild poppy so common in European grainfields. I have heard, however, that it has lately crossed the Atlantic, and I am not sorry for it. With our abundant harvests of wheat, we can well afford to pay now and then a loaf of bread for the cheerful radiance of this brilliant flower.

† Josselyn, who wrote about fifty years after the foundation of the first British colony in New England, says that the settlers at Plymouth had observed more than twenty English plants springing up spontaneously near their improvements.

Introduction of Foreign Plants.

"A negro slave of the great Cortez," says Humboldt, "was the first who sowed wheat in New Spain. He found three grains of it among the rice which had been brought from Spain as food for the soldiers."

About twenty years ago, a Japanese forage plant, the *Lespedeza striata*, whose seeds had been brought to the United States by some unknown accident, made its appearance in one of the Southern States. It spread spontaneously in various directions, and in a few years was widely diffused. It grows upon poor and exhausted soils, where the formation of a turf or sward by the ordinary grasses would be impossible, and where consequently no regular pastures or meadows can exist. It makes excellent fodder for stock, and though its value is contested, it is nevertheless generally thought a very important addition to the agricultural resources of the South.*

In most of the Southern countries of Europe, the sheep and horned cattle winter on the plains, but in the summer are

---

Every country has many plants not now, if ever, made use of by man, and therefore not designedly propagated by him, but which cluster around his dwelling, and continue to grow luxuriantly on the ruins of his rural habitation after he has abandoned it. The site of a cottage, the very foundation stones of which have been carried off, may often be recognized, years afterwards, by the rank weeds which cover it, though no others of the same species are found for miles.

"Mediæval Catholicism," says Vaupell, "brought us the red horsehoof—whose reddish-brown flower buds shoot up from the ground when the snow melts, and are followed by the large leaves—comfrey and snake-root, which grow only where there were convents and other dwellings in the Middle Ages." —*Bögens Indvandring i de Danske Skove*, pp. 1, 2.

* Accidents sometimes limit, as well as promote, the propagation of foreign vegetables in countries new to them. The Lombardy poplar is a diœcious tree, and is very easily grown from cuttings. In most of the countries into which it has been introduced the cuttings have been taken from the male, and as, consequently, males only have grown from them, the poplar does not produce seed in those regions. This is a fortunate circumstance, for otherwise this most worthless and least ornamental of trees would spread with a rapidity that would make it an annoyance to the agriculturist.

driven, sometimes many days' journey, to mountain pastures. Their coats and fleeces transport seeds in both directions. Hence we see Alpine plants in champaign districts, the plants of the plains on the borders of the glaciers, though in neither case do these vegetables ripen their seeds and propagate themselves. This explains the occurrence of tufts of common red clover with pallid and sickly flowers, on the flanks of the Alps at heights exceeding seven thousand feet.

The hortus siccus of a botanist may accidentally sow seeds from the foot of the Himalayas on the plains that skirt the Alps; and it is a fact of very familiar observation, that exotics, transplanted to foreign climates suited to their growth, often escape from the flower garden and naturalize themselves among the spontaneous vegetation of the pastures. When the cases containing the artistic treasures of Thorvaldsen were opened in the court of the museum where they are deposited, the straw and grass employed in packing them were scattered upon the ground, and the next season there sprang up from the seeds no less than twenty-five species of plants belonging to the Roman campagna, some of which were preserved and cultivated as a new tribute to the memory of the great Scandinavian sculptor, and at least four are said to have spontaneously naturalized themselves about Copenhagen.* The Turkish armies, in their incursions into Europe, brought Eastern vegetables in their train, and left the seeds of Oriental wall plants to grow upon the ramparts of Buda and Vienna.† In the campaign of 1814, the Russian troops brought, in the stuffing of their saddles and by other accidental means, seeds from the banks of the Dnieper to the valley of the Rhine, and even introduced the plants of the steppes into the environs of Paris.

The forage imported for the French army in the war of

---

* VAUPELL, *Bögens Indvandring i de Danske Skove*, p. 2.

† I believe it is certain that the Turks introduced tobacco into Hungary, and probable that they in some measure compensated the injury by introducing maize also, which, as well as tobacco, has been claimed as Hungarian by patriotic Magyars.

1870–1871 has introduced numerous plants from Northern Africa and other countries into France, and this vegetable emigration is so extensive and so varied in character, that it will probably have an important botanical, and even economical, effect on the flora of that country.[*]

The Canada thistle, *Erigeron Canadense*, which is said to have accompanied the early French voyagers to Canada from Normandy, is reported to have been introduced into other parts of Europe two hundred years ago by a seed which dropped out of the stuffed skin of an American bird.

Vegetable Power of Accommodation.

The vegetables which, so far as we know their history, seem to have been longest objects of human care, can, by painstaking industry, be made to grow under a great variety of circumstances, and some of them prosper nearly equally well when planted and tended on soils of almost any geological character; but the seeds of most of them vegetate only in artificially prepared ground, they have little self-sustaining power, and they soon perish when the nursing hand of man is withdrawn from them.

The vine *genus* is very catholic and cosmopolite in its habits, but particular *varieties* are extremely fastidious and exclusive in their requirements as to soil and climate. The stocks of many celebrated vineyards lose their peculiar qualities by transplantation, and the most famous wines are capable of production only in certain well-defined and for the most part narrow districts. The Ionian vine which bears the little stoneless grape known in commerce as the Zante currant, has resisted almost all efforts to naturalize it elsewhere, and is scarcely grown except in two or three of the Ionian islands and in a narrow territory on the northern shores of the Morea.

---

[*] In a communication lately made to the French Academy, M. Vibraye gives numerous interesting details on this subject, and says the appearance of the many new plants observed in France in 1871, "results from forage supplied from abroad, the seeds of which had fallen upon the ground. At the present time, several Mediterranean plants, chiefly Algerian, having braved the cold of an exceptionally severe winter, are being largely propagated, forming extensive meadows, and changing soil that was formerly arid and produced no vegetable of importance into veritable oases." See NATURE, Aug. 1, 1872, p. 263. We shall see on a following page that canals are efficient agencies in the unintentional interchange of organic life, vegetable as well as animal, between regions connected by such channels.

The attempts to introduce European varieties of the vine into the United States have not been successful except in California,* and it may be stated as a general rule that European forest and ornamental trees are not suited to the climate of North America, and that, at the same time, American garden vegetables are less luxuriant, productive and tasteful in Europe than in the United States.

The saline atmosphere of the sea is specially injurious both to seeds and to very many young plants, and it is only recently that the transportation of some very important vegetables across the ocean has been made practicable, through the invention of Ward's air-tight glass cases. By this means large numbers of the trees which produce the Jesuit's bark were successfully transplanted from America to the British possessions in the East, where this valuable plant may now be said to have become fully naturalized.†

Vegetables, naturalized abroad either by accident or design, sometimes exhibit a greatly increased luxuriance of growth.

---

* In 1869, a vine of a European variety planted in Sta. Barbara county in 1833 measured a foot in diameter four feet above the ground. Its ramifications covered ten thousand square feet of surface and it annually produces twelve thousand pounds of grapes. The bunches are sixteen or eighteen inches long, and weigh six or seven pounds.—*Letter from Commissioner of Land-Office*, dated May 13, 1869.

† See CLEGHORN, *Forests and Gardens of South India*, Edinburgh, 1861, and *The British Parliamentary Return on the Chinchona plant*, 1866. It has been found that the seeds of several species of *cinchona* preserve their vitality long enough to be transported to distant regions. The swiftness of steam navigation renders it possible to transport to foreign countries not only seeds but delicate living plants which could not have borne a long voyage by sailing vessels.

The European cardoon, an esculent thistle, has broken out from the gardens of the Spanish colonies on the La Plata, acquired a gigantic stature, and propagated itself, in impenetrable thickets, over hundreds of leagues of the Pampas; and the *Anacharis alsinastrum*, a water plant not much inclined to spread in its native American habitat, has found its way into English rivers, and extended itself to such a degree as to form a serious obstruction to the flow of the current, and even to navigation.

Not only do many wild plants exhibit a remarkable facility of accommodation, but their seeds usually possess great tenacity of life, and their germinating power resists very severe trials. Hence, while the seeds of many cultivated vegetables lose their vitality in two or three years, and can be transported safely to distant countries only with great precautions, the weeds that infest those vegetables, though not cared for by man, continue to accompany him in his migrations, and find a new home on every soil he colonizes. Nature fights in defence of her free children, but wars upon them when they have deserted her banners and tamely submitted to the dominion of man.*

Indeed, the faculty of spontaneous reproduction and perpetuation necessarily supposes a greater power of accommodation, within a certain range, than we find in most domesticated plants, for it would rarely happen that the seed of a wild plant would fall into ground as nearly similar, in composition and condition, to that where its parent grew, as the soils of different fields artificially prepared for growing a particular vegetable are to each other. Accordingly, though every wild species affects a habitat of a particular character, it is found that, if accidentally or designedly sown elsewhere, it will grow under conditions extremely unlike those of its birthplace. Cooper says: "We cannot say positively that *any* plant is uncultivable *anywhere* until it has been tried;" and this seems to be even more true of wild than of domesticated vegetation.

---

* Tempests, violent enough to destroy all cultivated plants, frequently spare those of spontaneous growth. I have often seen in Northern Italy, vineyards, maize fields, mulberry and fruit trees completely stripped of their foliage by hail, while the forest trees scattered through the meadows, and the shrubs and brambles which sprang up by the wayside, passed through the ordeal with scarcely the loss of a leaflet.

The wild plant is much hardier than the domesticated vegetable, and the same law prevails in animated brute and even human life. The beasts of the chase are more capable of endurance and privation and more tenacious of life, than the domesticated animals which most nearly resemble them. The savage fights on, after he has received half a dozen mortal wounds, the least of which would have instantly paralyzed the strength of his civilized enemy, and, like the wild boar, he has been known to press forward along the shaft of the spear which was transpiercing his vitals, and to deal a deathblow on the soldier who wielded it.

True, domesticated plants can be gradually acclimatized to bear a degree of heat or of cold, which, in their wild state, they would not have supported; the trained English racer outstrips the swiftest horse of the pampas or prairies, perhaps even the less systematically educated courser of the Arab; the strength of the European, as tested by the dynamometer, is greater than that of the New Zealander. But all these are instances of excessive development of particular capacities and faculties at the expense of general vital power. Expose untamed and domesticated forms of life, together, to an entire set of physical conditions equally alien to the former habits of both, so that every power of resistance and accommodation shall be called into action, and the wild plant or animal will live, while the domesticated will perish.

Agricultural Products of the United States.

According to the census of 1870, the United States had, on the first of June in that year, in round numbers, 189,000,000 acres of improved land, the quantity having been increased by

16,000,000 acres within the ten years next preceding.* Not to mention less important crops, this land produced, in the year ending on the day last mentioned, in round numbers, 288,000,000 bushels of wheat, 17,000,000 bushels of rye, 282,000,000 bushels of oats, 6,000,000 bushels of pease and beans, 30,000,000 bushels of barley, orchard fruits to the value of $47,000,000, 640,000 bushels of cloverseed, 580,000 bushels of other grass seed, 13,000 tons of hemp, 27,000,000 pounds of flax, and 1,730,000 bushels of flaxseed. These vegetable growths were familiar to ancient European agriculture, but they were all introduced into North America after the close of the sixteenth century.

Of the fruits of agricultural industry unknown to the Greeks and Romans, or too little employed by them to be of any commercial importance, the United States produced, in the same year, 74,000,000 pounds of rice, 10,000,000 bushels of buckwheat, 3,000,000 bales of cotton,† 87,000 hogsheads of cane sugar, 6,600,000 gallons of cane molasses, 16,000,000 gallons of sorghum molasses, all yielded by vegetables introduced into that country within two hundred years, and—with the exception of buckwheat, the origin of which is uncertain, and of cotton—all, directly or indirectly, from the East Indies; besides, from indigenous plants unknown to ancient agriculture, 761,000,000 bushels of Indian corn, 263,000,000 pounds of tobacco, 143,000,000 bushels of potatoes, 22,000,000 bushels of sweet potatoes, 28,000,000 pounds of maple sugar, and 925,000 gallons of maple molasses.* To all this we are to add 27,000,000 tons of hay,—produced partly by new, partly by long known, partly by exotic and partly by native herbs and grasses, the value of $21,000,000 in garden vegetables chiefly of European or Asiatic origin, 3,000,000 gallons of wine, and many minor agricultural products.†

---

* *Ninth Census of the United States*, 1872, p. 341. By "improved" land, in the reports on the census of the United States, is meant "cleared land used for grazing, grass, or tillage, or which is now fallow, connected with or belonging to a farm."—*Instructions to Marshals and Assistants, Census of* 1870.

† Cotton, though cultivated in Asia from the remotest antiquity, and known as a rare and costly product to the Latins and the Greeks, was not used by them except as an article of luxury, nor did it enter into their commerce to any considerable extent as a regular object of importation. The early voyagers found it in common use in the West Indies and in the provinces first colonized by the Spaniards; but it was introduced into the territory of the United States by European settlers, and did not become of any importance until after the Revolution. Cottonseed was sown in Virginia as early as 1621, but was not cultivated with a view to profit for more than a century afterwards. Sea-island cotton was first grown on the coast of Georgia in 1786, the seed having been brought from the Bahamas, where it had been introduced from Anguilla.—BIGELOW, *Les États-Unis en* 1863, p. 370.

The weight of this harvest of a year would be many times the tonnage of all the shipping of the United States at the close of the year 1870—and, with the exception of the maple sugar, the maple molasses, and the products of the Western prairie lands and of some small Indian clearings, it was all grown upon lands wrested from the forest by the European race within little more than two hundred years. The wants of Europe have introduced into the colonies of tropical America the sugar cane,‡ the coffee plant, the orange and the lemon, all of Oriental origin, have immensely stimulated the cultivation of the former two in the countries of which they are natives, and, of course, promoted agricultural operations which must have affected the geography of those regions to an extent proportionate to the scale on which they have been pursued.

---

* There is a falling off since 1860 of 11,000,000 pounds in the quantity of maple sugar and of more than a million gallons of maple molasses. The high price of cane sugar during and since the late civil war must have increased the product of maple sugar and molasses beyond what it otherwise would have been, but the domestic warfare on the woods has more than compensated this cause of increase.

† *Ramie, Boehmeria tenacissima*, a species of Chinese nettle producing a fibre which may be spun and woven, and which unites many of the properties of silk and of linen, has been completely naturalized in the United States, and results important to the industry of the country are expected from it.

‡ The sugar cane was introduced by the Arabs into Sicily and Spain as early as the ninth century, and though it is now scarcely grown in those localities, I am not aware of any reason to doubt that its cultivation might be revived with advantage. From Spain it was carried to the West Indies, though different varieties have since been introduced into those islands from other sources.

Useful American Plants grown in Europe.

America has partially repaid her debt to the Eastern continent. Maize and the potato are very valuable additions to the field agriculture of Europe and the East, and the tomato is no mean gift to the kitchen gardens of the Old World, though certainly not an adequate return for the multitude of esculent roots and leguminous plants which the European colonists carried with them.* I wish I could believe, with some, that America is not alone responsible for the introduction of the filthy weed, tobacco, the use of which is the most vulgar and pernicious habit engrafted by the semi-barbarism of modern civilization upon the less multifarious sensualism of ancient life; but the alleged occurrence of pipe-like objects in old Sclavonic, and, it has been said, in Hungarian sepulchres, is hardly sufficient evidence to convict those races of complicity in this grave offence against the temperance and the refinement of modern society.

Extirpation of Vegetables.

Lamentable as are the evils produced by the too general felling of the woods in the Old World, I believe it does not appear that any species of native forest tree has yet been extirpated by man on the Eastern continent. The roots, stumps, trunks, and foliage found in bogs are recognized as belonging to still extant species. Except in some few cases where there is historical evidence that foreign material was employed, the timber of the oldest European buildings, and even of the lacustrine habitations of Switzerland, is evidently the product of trees still common in or near the countries where such architectural remains are found; nor have the Egyptian catacombs themselves revealed to us the former existence of any woods not now familiar to us as the growth of still living trees.* It is, however, said that the yew tree, *Taxus baccata*, formerly very common in England, Germany, and—as we are authorized to infer from Theophrastus—in Greece, has almost wholly disappeared from the latter country, and seems to be dying out in Germany. The wood of the yew surpasses that of almost any other European tree in closeness and fineness of grain, and it is well known for the elasticity which of old made it so great a favorite with the English archer. It is much in request among wood carvers and turners, and the demand for it explains, in part, its increasing scarcity.

---

* John Smith mentions, in his *Historie of Virginia*, 1624, pease and beans as having been cultivated by the natives before the arrival of the whites, and there is no doubt, I believe, that several common cucurbitaceous plants are of American origin; but most, if not all the varieties of pease, beans, and other pod fruits now grown in American gardens, are from European and other foreign seed.

Cartier, A.D. 1535–'6, mentions "vines, great melons, cucumbers, gourds [courges], pease, beans of various colors, but not like ours," as common among the Indians of the banks of the St. Lawrence.—*Bref Recit*, etc., reprint. Paris, 1863, pp. 13, a; 14, b; 20, b; 31, a.

---

* Some botanists think that a species of water lily represented in many Egyptian tombs has become extinct, and the papyrus, which must have once been abundant in Egypt, is now found only in a very few localities near the mouth of the Nile. It grows very well and ripens its seeds in the waters of the Anapus near Syracuse, and I have seen it in garden ponds at Messina and in Malta. There is no apparent reason for believing that it could not be easily cultivated in Egypt, to any extent, if there were any special motive for encouraging its growth.

Silphium, a famous medicinal plant of Lybia and of Persia, seems to have disappeared entirely. At any rate there is no proof that it now exists in either of those regions. The Silphium of Greek and Roman commerce appears to have come wholly from Cyrene, that from the Asiatic deserts being generally of less value, or, as Strabo says, perhaps of an inferior variety. The province near Cyrene which produced it was very limited, and according to Strabo (ed. Casaubon, p. 837), it was at one time almost entirely extirpated by the nomade Africans who invaded the province and rooted out the plant.

The vegetable which produced the Balm of Gilead has not been found in modern times, although the localities in which it anciently grew have been carefully explored.

It is also asserted that no insect depends upon it for food or shelter, or aids in its fructification, and birds very rarely feed upon its berries: these are circumstances of no small importance, because the tree hence wants means of propagation or diffusion common to so many other plants. But it is alleged that the reproductive power of the yew is exhausted, and that it can no longer be readily propagated by the natural sowing of its seeds, or by artificial methods. If further investigation and careful experiment should establish this fact, it will go far to show that a climatic change, of a character unfavorable to the growth of the yew, has really taken place in Germany, though not yet proved by instrumental observation, and the most probable cause of such change would be found in the diminution of the area covered by the forests.

The industry of man is said to have been so successful in the local extirpation of noxious or useless vegetables in China, that, with the exception of a few water plants in the rice grounds, it is sometimes impossible to find a single weed in an extensive district; and the late eminent agriculturist, Mr. Coke, is reported to have offered in vain a considerable reward for the detection of a weed in a large wheatfield on his estate in England. In these cases, however, there is no reason to suppose that diligent husbandry has done more than to eradicate the pests of agriculture within a comparatively limited area, and the cockle and the darnel will probably remain to plague the slovenly cultivator as long as the cereal grains continue to bless him.*

---

* Although it is not known that man has absolutely extirpated any vegetable, the mysterious diseases which have, for the last twenty years, so injuriously affected the potato, the vine, the orange, the olive, and silk husbandry, are ascribed by some to a climatic deterioration produced by excessive destruction of the woods. As will be seen in the next chapter, a retardation in the period of spring has been observed in numerous localities in Southern Europe, as well as in the United States, and this change has been thought to favor the multiplication of the obscure parasites which cause the injury to the vegetables just mentioned.

Babinet supposes the parasites which attack the grape and the potato to be

All the operations of rural husbandry are destructive to spontaneous vegetation by the voluntary substitution of domestic for wild plants, and, as we have seen, the armies of the colonist are attended by troops of irregular and unrecognized camp-followers, which soon establish and propagate themselves over the new conquests. These unbidden and hungry guests—the gipsies of the vegetable world—often have great aptitude for accommodation and acclimation, and sometimes even crowd out the native growth to make room for themselves. The botanist Latham informs us that indigenous flowering plants,

---

animal, not vegetable, and he ascribes their multiplication to excessive manuring and stimulation of the growth of the plants on which they live. They are now generally, if not universally, regarded as vegetable, and if they are so, Babinet's theory would be even more plausible than on his own supposition.—*Études et Lectures*, ii., p. 269.

It is a fact of some interest in agricultural economy, that the oïdium, which is so destructive to the grape, has produced no pecuniary loss to the proprietors of the vineyards in France. "The price of wine," says Lavergne, "has quintupled, and as the product of the vintage has not diminished in the same proportion, the crisis has been, on the whole, rather advantageous than detrimental to the country."—*Économie Rurale de la France*, pp. 263, 264.

France produces a large surplus of wines for exportation, and the sales to foreign consumers are the principal source of profit to French vinegrowers. In Northern Italy, on the contrary, which exports little wine, there has been no such increase in the price of wine as to compensate the great diminution in the yield of the vines, and the loss of this harvest is severely felt. In Sicily, however, which exports much wine, prices have risen as rapidly as in France. Waltershausen informs us that in the years 1838-'42, the red wine of Mount Etna sold at the rate of one kreuzer and a half, or one cent the bottle, and sometimes even at but two thirds that price, but that at present it commands five or six times as much.

The grape disease has operated severely on small cultivators whose vineyards only furnished a supply for domestic use, but Sicily has received a compensation in the immense increase which it has occasioned in both the product and the profits of the sulphur mines. Flour of sulphur is applied to the vine as a remedy against the disease, and the operation is repeated from two to three or four—and sometimes even eight or ten—times in a season. Hence there is a great demand for sulphur in all the vine-growing countries of Europe, and Waltershausen estimates the annual consumption of that mineral for this single purpose at 850,000 *centner*, or more than forty thousand tons. The price of sulphur has risen in about the same proportion as that of wine.—WALTERSHAUSEN, *Ueber den Sicilianischen Ackerbau*, pp. 19, 20.

once abundant on the North-Western prairies, have been so nearly extirpated by the inroads of half-wild vegetables which have come in the train of the Eastern immigrant, that there is reason to fear that, in a few years, his *herbarium* will constitute the only evidence of their former existence.*

There are plants—themselves perhaps sometimes stragglers from their proper habitat—which are found only in small numbers and in few localities. These are eagerly sought by the botanist, and some such species are believed to be on the very verge of extinction, from the zeal of collectors.

Animal Life as a Geological and Geographical Agency.

The quantitative value of animated life, as a geological agency, seems to be inversely as the volume of the individual organism; for nature supplies by numbers what is wanting in the bulk of the animal out of whose remains or structures she forms strata covering whole provinces, and builds up from the depths of the sea large islands, if not continents. There are, it is true, near the mouths of the great Siberian rivers which empty themselves into the Polar Sea, drift islands composed, in an incredibly large proportion, of the bones and tusks of elephants, mastodons, and other huge pachyderms, and many extensive caves in various parts of the world are half filled with the skeletons of quadrupeds, sometimes lying loose in the earth, sometimes cemented together into an osseous breccia by a calcareous deposit or other binding material. These remains of large animals, though found in comparatively late formations, generally belong to extinct species, and their modern congeners or representatives do not exist in sufficient numbers to be of sensible importance in geology or in geography by the mere mass of their skeletons.† But the vegetable products found with them, and, in rare cases, in the stomachs of some of them, are those of yet extant plants; and besides this evidence, the discovery of works of human art, deposited in juxtaposition with fossil bones, and evidently at the same time and by the same agency which buried these latter—not to speak of human bones found in the same strata—proves that the animals whose former existence they testify were contemporaneous with man,

---

* *Report of Commissioner of Agriculture of the United States* for 1870.

† Could the bones and other relics of the domestic quadrupeds destroyed by disease or slaughtered for human use in civilized countries be collected into large deposits, as obscure causes have gathered together those of extinct

---

animals, they would soon form aggregations which might almost be called mountains. There were in the United States, in 1870, as we shall see hereafter, nearly one hundred millions of horses, black cattle, sheep, and swine. There are great numbers of all the same animals in the British American Provinces and in Mexico, and there are large herds of wild horses on the plains, and of tamed among the independent Indian tribes of North America. It would perhaps not be extravagant to suppose that all these cattle may amount to two thirds as many as those of the United States, and thus we have in North America a total of 160,000,000 domestic quadrupeds belonging to species introduced by European colonization, besides dogs, cats, and other four-footed household pets and pests, also of foreign origin.

If we allow half a solid foot to the skeleton and other slowly destructible parts of each animal, the remains of these herds would form a cubical mass measuring not much short of four hundred and fifty feet to the side, or a pyramid equal in dimensions to that of Cheops, and as the average life of these animals does not exceed six or seven years, the accumulations of their bones, horns, hoofs, and other durable remains would amount to at least fifteen times as great a volume in a single century. It is true that the actual mass of solid matter, left by the decay of dead domestic quadrupeds and permanently added to the crust of the earth, is not so great as this calculation makes it. The greatest proportion of the soft parts of domestic animals, and even of the bones, is soon decomposed, through direct consumption by man and other carnivora, industrial use, and employment as manure, and enters into new combinations in which its animal origin is scarcely traceable; there is, nevertheless, a large annual residuum, which, like decayed vegetable matter, becomes a part of the superficial mould; and in any event, brute life immensely changes the form and character of the superficial strata, if it does not sensibly augment the quantity of the matter composing them.

The remains of man, too, add to the earthy coating that covers the face of the globe. The human bodies deposited in the catacombs during the long, long ages of Egyptian history, would perhaps build as large a pile as one generation of the quadrupeds of the United States. In the barbarous days of old Moslem warfare, the conquerors erected large pyramids of human skulls. The soil of cemeteries in the great cities of Europe has sometimes been raised several feet by the deposit of the dead during a few generations. In the East, and possibly even extirpated by him.* I do not propose to enter upon the thorny question, whether the existing races of man are genealogically connected with these ancient types of humanity, and I advert to these facts only for the sake of the suggestion, that man, in his earliest known stages of existence, was probably a destructive power upon the earth, though perhaps not so emphatically as his present representatives.

The larger wild animals are not now numerous enough in any one region to form extensive deposits by their remains; but they have, nevertheless, a certain geographical importance. If the myriads of large browsing and grazing quadrupeds which wander over the plains of Southern Africa—and the slaughter of which by thousands is the source of a ferocious pleasure and

---

Turks and Christians alike bury bodies but a couple of feet beneath the surface. The grave is respected as long as the tombstone remains, but the sepultures of the ignoble poor, and of those whose monuments time or accident has removed, are opened again and again to receive fresh occupants. Hence the ground in Oriental cemeteries is pervaded with relics of humanity, if not wholly composed of them; and an examination of the soil of the lower part of the *Petit Champ des Morts*, at Pera, by the naked eye alone, shows the observer that it consists almost exclusively of the comminuted bones of his fellow-man.

* The bones of mammoths and mastodons, in many instances, appear to have been grazed or cut by flint arrow-heads or other stone weapons, and the bones of animals now extinct are often wrought into arms and utensils, or split to extract the marrow. These accounts have often been discredited, because it has been assumed that the extinction of these animals was more ancient than the existence of man. Recent discoveries render it certain that this conclusion has been too hastily adopted.

On page 143 of the *Antiquity of Man*, Lyell remarks that man "no doubt played his part in hastening the era of the extinction" of the large pachyderms and beasts of prey; but, as contemporaneous species of other animals, which man cannot be supposed to have extirpated, have also become extinct, he argues that the disappearance of the quadrupeds in question cannot be ascribed to human action alone.

On this point it may be observed that, as we cannot know what precise physical conditions were necessary to the existence of a given extinct organism, we cannot say how far such conditions may have been modified by the action of man, and he may therefore have influenced the life of such organisms in ways, and to an extent, of which we can form no just idea.

a brutal triumph to professedly civilized hunters—if the herds of the American bison, which are numbered by hundreds of thousands, do not produce visible changes in the forms of terrestrial surface, they have at least an immense influence on the growth and distribution of vegetable life, and, of course, indirectly upon all the physical conditions of soil and climate between which and vegetation a mutual interdependence exists.

In the preceding chapter I referred to the agency of the beaver in the formation of bogs as producing sensible geographical effects.

I am disposed to think that more bogs in the Northern States owe their origin to beavers than to accidental obstructions of rivulets by wind-fallen or naturally decayed trees; for there are few swamps in those States, at the outlets of which we may not, by careful search, find the remains of a beaver dam. The beaver sometimes inhabits natural lakelets and even large rivers like the Upper Mississippi, when the current is not too rapid, but he prefers to owe his pond to his own ingenuity and toil. The reservoir once constructed, its inhabitants rapidly multiply so long as the trees, and the harvests of pond lilies and other aquatic plants on which this quadruped feeds in winter, suffice for the supply of the growing population. But the extension of the water causes the death of the neighboring trees, and the annual growth of those which could be reached by canals and floated to the pond soon becomes insufficient for the wants of the community, and the beaver metropolis now sends out expeditions of discovery and colonization. The pond gradually fills up, by the operation of the same causes as when it owes its existence to an accidental obstruction, and when, at last, the original settlement is converted into a bog by the usual processes of vegetable life, the remaining inhabitants abandon it and build on some virgin brooklet a new city of the waters.*

---

* I find confirmation of my own observations on this point (published in 1863) in the *North-West Passage by Land* of Milton and Cheadle, London, 1865. These travellers observed "a long chain of marshes formed by the damming up of a stream which had now ceased to exist," Chap. X. In Chap. XII.

Influence of Animal Life on Vegetation.

The influence of wild quadrupeds upon vegetable life has been little studied, and not many facts bearing upon it have been recorded, but, so far as it is known, it appears to be con-

---

they state that "nearly every stream between the Pembina and the Athabasca —except the large river McLeod—appeared to have been destroyed by the agency of the beaver," and they question whether the vast extent of swampy ground in that region "has not been brought to this condition by the work of beavers who have thus destroyed, by their own labor, the streams necessary to their own existence."

But even here nature provides a remedy, for when the process of "consolidation" referred to in treating of bogs in the first chapter shall have been completed, and the forest re-established upon the marshes, the water now diffused through them will be collected in the lower or more yielding portions, cut new channels for their flow, become running brooks, and thus restore the ancient aspect of the surface.

The authors add the curious observation that the beavers of the present day seem to be a degenerate race, as they neither fell large trees nor construct great dams, while their progenitors cut down trees two feet in diameter and dammed up rivers a hundred feet in width. The change in the habits of the beaver is probably due to the diminution of their numbers since the introduction of fire-arms, and to the fact that their hydraulic operations are more frequently interrupted by the encroachments of man.

In the valley of the Yellowstone, which has but lately been much visited by the white man, Hayden saw stumps of trees thirty inches in diameter which had been cut down by beavers.—*Geological Survey of Wyoming*, p. 135.

The American beaver closely resembles his European congener, and I believe most naturalists now regard them as identical. A difference of species had been inferred from a difference in their modes of life, the European animal being solitary and not a builder, the American gregarious and constructive. But late careful researches in Germany have shown the former existence of numerous beaver dams in that country, though the animal, having become too rare to form colonies, has of course ceased to attempt works which require the co-operation of numerous individuals.—SCHLEIDEN, *Für Baum und Wald*, Leipzig, 1870, p. 68.

On the question of identity and on all others relating to this interesting animal, see L. H. MORGAN's important monograph, *The American Beaver and his Works*, Philadelphia, 1868. Among the many new facts observed by this investigator is the construction of canals by the beaver to float trunks and branches of trees to his ponds. These canals are sometimes 600 or 700 feet long, with a width of two or three feet and a depth of one to one and a half.

servative rather than pernicious. Few wild animals depend for their subsistence on vegetable products obtainable only by the destruction of the plant, and they seem to confine their consumption almost exclusively to the annual harvest of leaf or twig, or at least of parts of the vegetable easily reproduced. If there are exceptions to this rule, they are in cases where the numbers of the animal are so proportioned to the abundance of the vegetable that there is no danger of the extermination of the plant from the voracity of the quadruped, or of the extinction of the quadruped from the scarcity of the plant.* In diet and natural wants the bison resembles the ox, the ibex and the chamois assimilate themselves to the goat and the sheep; but while the wild animal does not appear to be a destructive agency in the garden of nature, his domestic congeners are eminently so.* This is partly from the change of habits resulting from domestication and association with man, partly from the fact that the number of reclaimed animals is not determined by the natural relation of demand and spontaneous supply which regulates the multiplication of wild creatures, but by the convenience of man, who is, in comparatively few things, amenable to the control of the merely physical arrangements of nature. When the domesticated animal escapes from human jurisdiction, as in the case of the ox, the horse, the goat, and perhaps the ass—which, so far as I know, are the only well-authenticated instances of the complete emancipation of household quadrupeds—he becomes again an unresisting subject of nature, and all his economy is governed by the same laws as that of his fellows which have never been enslaved by man; but, so long as he obeys a human lord, he is an auxiliary in the warfare his master is ever waging against all existences except those which he can tame to a willing servitude.

---

* European foresters speak of the action of the squirrel as injurious to trees. Doubtless this is sometimes true in the case of artificial forests, but in woods of spontaneous growth, ordered and governed by nature, the squirrel does not attack trees, or at least the injury he may do is too trifling to be perceptible, but he is a formidable enemy to the plantation. "The squirrels bite the cones of the pine and consume the seed which might serve to restock the wood; they do still more mischief by gnawing off, near the leading shoot, a strip of bark, and thus often completely girdling the tree. Trees so injured must be felled, as they would never acquire a vigorous growth. The squirrel is especially destructive to the pine in Sologne, where he gnaws the bark of trees twenty or twenty-five years old." But even here, nature sometimes provides a compensation, by making the appetite of this quadruped serve to prevent an excessive production of seed cones, which tends to obstruct the due growth of the leading shoot. "In some of the pineries of Brittany which produce cones so abundantly as to strangle the development of the leading shoot of the maritime pine, it has been observed that the pines are most vigorous where the squirrels are most numerous, a result attributed to the repression of the cones by this rodent."—BOITEL, *Mise en valeur des Terres pauvres*, p. 50.

Very interesting observations, on the agency of the squirrel and other small animals in planting and in destroying nuts and other seeds of trees, may be found in a paper on the Succession of Forests in Thoreau's *Excursions*, pp. 135 *et seqq.*

I once saw several quarts of beech-nuts taken from the winter quarters of a family of flying squirrels in a hollow tree. The kernels were neatly stripped of their shells and carefully stored in a dry cavity.

Origin and Transfer of Domestic Quadrupeds.

Civilization is so intimately associated with certain inferior forms of animal life, if not dependent on them, that cultivated man has never failed to accompany himself, in all his migrations, with some of these humble attendants. The ox, the horse, the sheep, and even the comparatively useless dog and cat, as well as several species of poultry, are voluntarily transferred by every emigrant colony, and they soon multiply to numbers far exceeding those of the wild genera most nearly corresponding to them.*

---

* Evelyn thought the depasturing of grass by cattle serviceable to its growth. "The biting of cattle," he remarks, "gives a gentle loosening to the roots of the herbage, and makes it to grow fine and sweet, and their very breath and treading as well as soil, and the comfort of their warm bodies, is wholesome and marvellously cherishing."—*Terra, or Philosophical Discourse of Earth*, p. 36.

In a note upon this passage, Hunter observes: "Nice farmers consider the lying of a beast upon the ground, for one night only, as a sufficient tilth for the year. The breath of graminivorous quadrupeds does certainly enrich the roots of grass; a circumstance worthy of the attention of the philosophical farmer."—*Terra*, same page.

The "philosophical farmer" of the present day will not adopt these opinions without some qualification, and they certainly are not sustained by American observation.

The *Report of the Department of Agriculture* for March and April, 1872, states that the native grasses are disappearing from the prairies of Texas, especially on the bottom-lands, depasturing by cattle being destructive to them.

Of the origin of our domestic animals, we know historically nothing, because their domestication belongs to the ages which preceded written annals; but though they cannot all be specifically identified with now extant wild animals, it is presumable that they have been reclaimed from an originally wild state. Ancient writers have preserved to us fewer data respecting the introduction of domestic animals into new countries than respecting the transplantation of domestic vegetables. Ritter, in his learned essay on the camel, has shown that this animal was not employed by the Egyptians until a comparatively late period in their history; † that he was unknown to the Carthaginians until after the downfall of their commonwealth; and that his first appearance in Western Africa is more recent still. The Bactrian camel was certainly brought from Asia Minor to the Northern shores of the Black Sea, by the Goths, in the third or fourth century, and the buffalo first appeared in Italy about A.D. 600, though it is unknown whence or by whom he was introduced.* The Arabian single-humped camel, or dromedary, has been carried to the Canary Islands, partially introduced into Australia, Greece, Spain, and even Tuscany, experimented upon to little purpose in Venezuela, and finally imported by the American Government into Texas and New Mexico, where it finds the climate and the vegetable products best suited to its wants, and promises to become a very useful agent in the promotion of the special civilization for which those regions are adapted.

---

* The rat and the mouse, though not voluntarily transported, are passengers by every ship that sails for a foreign port, and several species of these quadrupeds have, consequently, much extended their range and increased their numbers in modern times. From a story of Heliogabalus related by LAMPRIDIUS, *Hist. Aug. Scriptores*, ed. Casaubon, 1690, p. 110, it would seem that mice at least were not very common in ancient Rome. Among the capricious freaks of that emperor, it is said that he undertook to investigate the statistics of the arachnoid population of the capital, and that 10,000 pounds of spiders (or spiders' webs—for *aranea* is equivocal) were readily collected; but when he got up a mouse-show, he thought ten thousand mice a very fair number. Rats are not less numerous in all great cities; and in Paris, where their skins are used for gloves, and their flesh, it is whispered, in some very complex and equivocal dishes, they are caught by legions. I have read of a manufacturer who contracted to buy of the rat-catchers, at a high price, all the rat-skins they could furnish before a certain date, and failed, within a week, for want of capital, when the stock of peltry had run up to 600,000.

Civilization has not contented itself with the introduction of domestic animals alone. The English sportsman imports foxes from the continent, and Grimalkin-like turns them loose in order that he may have the pleasure of chasing them afterwards.

† The horse and the ass were equally unknown to ancient Egypt, and do not appear in the sculptures before the XV. and XVI. dynasties. But even then, the horse was only known as a draught animal, and the only representation of

Quadrupeds, both domestic and wild, bear the privations and discomforts of long voyages better than would be supposed. The elephant, the giraffe, the rhinoceros, and even the hippopotamus, do not seem to suffer much at sea. Some of the camels imported by the U. S. government into Texas from the Crimea and Northern Africa were a whole year on shipboard. On the other hand, George Sand, in *Un Hiver au Midi*, gives an amusing description of the sea-sickness of swine in the short passage from the Baleares to Barcelona.

America had no domestic quadruped but a species of dog, the lama tribe, and, to a certain extent, the bison or buffalo.† Of

---

a horseman yet found in the Egyptian tombs is on the blade of a battle axe of uncertain origin and period.

* *Erdkunde*, viii., *Asien*, 1ste *Abtheilung*, pp. 660, 758. Hehn, *Kulturpflanzen*, p. 345.

† See Chapter III., *post;* also Humboldt, *Ansichten der Natur*, i., p. 71. From the anatomical character of the bones of the urus, or auerochs, found among the relics of the lacustrine population of ancient Switzerland, and from other circumstances, it is inferred that this animal had been domesticated by that people; and it is stated, I know not upon what authority, in *Le Alpi che cingono l'Italia*, that it had been tamed by the Veneti also. See Lyell, *Antiquity of Man*, pp. 24, 25, and the last-named work, p. 480. This is a fact of much interest, because it is one of the very few *historically* known

course, it owes the horse, the ass, the ox, the sheep, the goat, and the swine, as does also Australia, to European colonization. Modern Europe has, thus far, not accomplished much in the way of importation of new animals, though some interesting essays have been made. The reindeer was successfully introduced into Iceland about a century ago, while similar attempts failed, about the same time, in Scotland. The Cashmere or Thibet goat was brought to France a generation since, and succeeds well. The same or an allied species and the Asiatic buffalo were carried to South Carolina about the year 1850, and the former, at least, is thought likely to prove of permanent value in the United States.* The yak, or Tartary ox, seems to thrive in France, and it is hoped that success will attend the present efforts to introduce the South American alpaca into Europe.†

---

instances of the extinction of a domestic quadruped, and the extreme improbability of such an event gives some countenance to the theory of the identity of the domestic ox with, and its descent from, the urus.

* The goat introduced into South Carolina was brought from the district of Angora, in Asia Minor, which has long been celebrated for flocks of this valuable animal. It is calculated that more than a million of these goats are raised in that district, and it is commonly believed that the Angora goat and its wool degenerate when transported. Probably this is only an invention of the shepherds to prevent rivals from attempting to interfere with so profitable a monopoly. But if the popular prejudice has any foundation, the degeneracy is doubtless to be attributed to ignorance of the special treatment which long experience has taught the Angora shepherds, and the consequent neglect of such precautions as are necessary to the proper care of the animal. Throughout nearly the whole territory of the United States the success of the Angora goat is perfect, and it would undoubtedly thrive equally well in Italy, though it is very doubtful whether in either country the value of its fleece would compensate the damage it would do to the woods.

† The reproductive powers of animals, as well as of plants, seem to be sometimes stimulated in an extraordinary way by transfer to a foreign clime. The common warren rabbit introduced by the early colonists into the island of Madeira multiplied to such a degree as to threaten the extirpation of vegetation, and in Australia the same quadruped has become so numerous as to be a very serious evil. The colonists are obliged to employ professional rabbit-hunters, and one planter has enclosed his grounds by four miles of solid wall, at an expense of $6,000, to protect his crops against these ravagers.—*Revue des Eaux et Forêts*, 1870, p. 38.

According to the census of the United States for 1870,* the total number of horses in all the States of the American Union, was, in round numbers, 7,100,000; of asses and mules, 1,100,000; of the ox tribe, 25,000,000; of sheep, 28,000,000; and of swine, 25,000,000. The only indigenous North American quadruped sufficiently gregarious in habits, and sufficiently multiplied in numbers, to form really large herds, is the bison, or, as he is commonly called in America, the buffalo; and this animal is confined to the prairie region of the Mississippi basin, a small part of British America, and Northern Mexico. The engineers sent out to survey railroad routes to the Pacific estimated the number of a single herd of bisons seen within the last fifteen years on the great plains near the Upper Missouri, at not less than 200,000, and yet the range occupied by this animal is now very much smaller in area than it was when the whites first established themselves on the prairies.† But it must be remarked that the American buffalo is a migratory animal, and that, at the season of his annual journeys, the whole stock of a vast extent of pasture-ground is collected into a single army, which is seen at or very near any one point only for a few days during the entire season. Hence there is risk of great error in estimating the numbers of the bison in a given district from the magnitude of the herds seen at or about the same time at a single place of observation; and, upon the whole, it is neither proved nor probable that the bison was ever, at any one time, as numerous in North America as the domestic bovine species is at present. The elk, the moose, the musk ox, the caribou, and the smaller quadrupeds popularly embraced under the general name of deer, though sufficient for the wants of a sparse savage population, were never numerically very abundant, and the carnivora which fed upon them were still less so. It is almost needless to add that the Rocky Mountain sheep and goat must always have been very rare.

---

* In the enumeration of farm stock, "sucking pigs, spring lambs, and calves," are omitted. I believe they are included in the numbers reported by the census of 1860. Horses and horned cattle in towns and cities were excluded from both enumerations, the law providing for returns on these points from rural districts only. On the whole, there is a diminution in the number of all farm stock, except sheep, since 1860. This is ascribed by the Report to the destruction of domestic quadrupeds during the civil war, but this hardly explains the reduction in the number of swine from 39,000,000 in 1860 to 25,000,000 in 1870.

† "About five miles from camp we ascended to the top of a high hill, and for a great distance ahead every square mile seemed to have a herd of buffalo upon it. Their number was variously estimated by the members of the party; by some as high as half a million. I do not think it any exaggeration to set it down at 200,000."—STEVENS'S *Narrative and Final Report. Reports of Explorations and Surveys for Railroad to Pacific*, vol. xii., book i., 1860.

The next day the party fell in with a "buffalo trail," where at least 100,000 were thought to have crossed a slough.

As late as 1868, Sheridan's party estimated the number of bisons seen by them in a single day at 200,000.—*Sheridan's Troopers on the Border*, 1868, p. 41.

Summing up the whole, then, it is evident that the wild quadrupeds of North America, even when most numerous, were few compared with their domestic successors, that they required a much less supply of vegetable food, and consequently were far less important as geographical elements than the many millions of hoofed and horned cattle now fed by civilized man on the same continent.

Extirpation of Wild Quadrupeds.

Although man never fails greatly to diminish, and is perhaps destined ultimately to exterminate, such of the larger wild quadrupeds as he cannot profitably domesticate, yet their numbers often fluctuate, and even after they seem almost extinct, they sometimes suddenly increase, without any intentional steps to promote such a result on his part. During the wars which followed the French Revolution, the wolf multiplied in many parts of Europe, partly because the hunters were withdrawn from the woods to chase a nobler game, and partly because the bodies of slain men and horses supplied this voracious quadruped with more abundant food.* The same animal became again more numerous in Poland after the general disarming of the rural population by the Russian Government. On the other hand, when the hunters pursue the wolf, the graminivorous wild quadrupeds increase, and thus in turn promote the multiplication of their great four-footed destroyer by augmenting the supply of his nourishment. So long as the fur of the beaver was extensively employed as a material for hats, it bore a very high price, and the chase of this quadruped was so keen that naturalists feared its speedy extinction. When a Parisian manufacturer invented the silk hat, which soon came into almost universal use, the demand for beavers' fur fell off, and this animal—whose habits are an important agency in the formation of bogs and other modifications of forest nature—immediately began to increase, reappeared in haunts which he had long abandoned, and can no longer be regarded as rare enough to be in immediate danger of extirpation. Thus the convenience or the caprice of Parisian fashion has unconsciously exercised an influence which may sensibly affect the physical geography of a distant continent.

---

* During the late civil war in America, deer and other animals of the chase multiplied rapidly in the regions of the Southern States which were partly depopulated and deprived of their sportsmen by the military operations of the contest, and the bear is said to have reappeared in districts where he had not been seen in the memory of living men.

Since the invention of gunpowder, some quadrupeds have completely disappeared from many European and Asiatic countries where they were formerly numerous. The last wolf was killed in Great Britain two hundred years ago, and the bear was extirpated from that island still earlier. The lion is believed to have inhabited Asia Minor and Syria, and probably Greece and Sicily also, long after the commencement of the historical period, and he is even said to have been not yet extinct in the first-named two of these countries at the time of the first Crusade.*

The British wild ox is extinct except in a few English and

---

* In maintaining the recent existence of the lion in the countries named in the text, naturalists have, perhaps, laid too much weight on the frequent occurrence of representations of this animal in sculptures apparently of a historical character. It will not do to argue, twenty centuries hence, that the lion and the unicorn were common in Great Britain in Queen Victoria's time, because they are often seen "fighting for the crown" in the carvings and paintings of that period. Many palæontologists, however, identify the great

Scottish parks, while in Irish bogs of no great apparent antiquity are found antlers which testify to the former existence of a stag much larger than any extant European species. Two large graminivorous or browsing quadrupeds, the ur and the schelk, once common in Germany, have been utterly extirpated, the eland and the auerochs nearly so. The Nibelungen-Lied, which, in the oldest form preserved to us, dates from about the year 1200, though its original composition no doubt belongs to an earlier period, thus sings:

> Then slowe the dowghtie Sigfrid a wisent and an elk,
> He smote four stoute uroxen and a grim and sturdie schelk.*

Modern naturalists identify the elk with the eland, the wisent with the auerochs. The period when the ur and the schelk became extinct is not known. The auerochs survived in Prussia until the middle of the last century, but unless it is identical with a similar quadruped said to be found on the Caucasus, it now exists only in the Russian imperial forest of Bialowitz where about a thousand are still preserved, and in some great menageries, as for example that at Schönbrunn, near Vienna, which, in 1852, had four specimens. The eland, which is closely allied to the American wapiti if not specifically the same animal, is still kept in the royal preserves of Prussia, to the number of four or five hundred individuals. The chamois

---

cat-like animal, whose skeletons are frequently found in British bone-caves, with the lion of our times.

The leopard (*panthera*), though already growing scarce, was found in Cilicia in Cicero's time. See his letter to Cœlius, *Epist. ad Diversos*, Lib. II., Ep. 11.

* Dar nach sluoger schiere, einen wisent unde elch.
Starker ure viere, unt einen grimmen schelch.
XVI. *Aventiure.*

The testimony of the *Nibelungen-Lied* is not conclusive evidence that these quadrupeds existed in Germany at the time of the composition of that poem. It proves too much; for, a few lines above those just quoted, Sigfrid is said to have killed a lion, an animal which the most patriotic Teuton will hardly claim as a denizen of mediæval Germany.

is becoming rare, and the ibex or steinbock, once common in all the high Alps, is now believed to be confined to the Cogne mountains in Piedmont, between the valleys of the Dora Baltea and the Orco, though it is said that a few still linger about the Grandes Jorasses near Cormayeur.

The chase, which in early stages of human life was a necessity, has become with advancing civilization not merely a passion but a dilettanteism, and the cruel records of this pastime are among the most discreditable pages in modern literature. It is true that in India and other tropical countries, the number and ferocity of the wild beasts not only justify but command a war of extermination against them, but the indiscriminate slaughter of many quadrupeds which are favorite objects of the chase can urge no such apology. Late official reports from India state the number of human victims of the tiger, the leopard, the wolf and other beasts of prey, in ten "districts," at more than twelve thousand within three years, and we are informed on like authority that within the last six years more than ten thousand men, women, and children have perished in the same way in the Presidency of Bengal alone. One tiger, we are told, had killed more than a hundred people, and finally stopped the travel on an important road, and another had caused the desertion of thirteen villages and thrown 250 square miles out of cultivation. In such facts we find abundant justification of the slaying of seven thousand tigers, nearly six thousand leopards, and twenty-five hundred other ravenous beasts in the Bengal Presidency, in the space of half a dozen years. But the humane reader will not think the value of the flesh, the skin, and other less important products of inoffensive quadrupeds a satisfactory excuse for the ravages committed upon them by amateur sportsmen as well as by professional hunters. In 1861, it was computed that the supply of the English market with ivory cost the lives of 8,000 elephants. Others make the number much larger, and it is said that half as much ivory is consumed in the United States as in Great Britain. In Ceylon, where the elephants are numerous and destructive to the crops, as well as dangerous to travellers, while their tusks are small and of comparatively little value, the government pays a small reward for killing them. According to Sir Emerson Tennant,* in three years prior to 1848, the premium was paid for 3,500 elephants in a part of the northern district, and between 1851 and 1856 for 2,000 in the southern district. Major Rogers, famous as an elephant shooter in Ceylon, ceased to count his victims after he had slain 1,300, and Cumming in South Africa sacrificed his hecatombs every month.

In spite of the rarity of the chamois, his cautious shyness, and the comparative inaccessibility of his favorite haunts, Colani of Pontresina, who died in 1837, had killed not less than 2,000 of these animals; Küng, who is still living in the Upper Engadine, 1,500; Hitz, 1,300, and Zwichi an equal number; Soldani shot 1,100 or 1,200 in the mountains which enclose the Val Bregaglia, and there are many living hunters who can boast of having killed from 500 to 800 of these interesting quadrupeds.†

In America, the chase of the larger quadrupeds is not less destructive. In a late number of the *American Naturalist*, the present annual slaughter of the bison is calculated at the enormous number of 500,000, and the elk, the moose, the caribou, and the more familiar species of deer furnish, perhaps, as many victims. The most fortunate deer-hunter I have personally known in New England had killed but 960; but in the northern part of the State of New York, a single sportsman is said to have shot 1,500, and this number has been doubtless exceeded by zealous Nimrods of the West.

But so far as numbers are concerned, the statistics of the fur-trade furnish the most surprising results. Russia sends annually to foreign markets not less than 20,000,000 squirrel skins, Great Britain has sometimes imported from South America 600,000 nutria skins in a year. The Leipzig market receives annually nearly 200,000 ermine, and the Hudson Bay Company is said to have occasionally burnt 20,000 ermine skins in order that the market might not be overstocked.

---

* *Natural History of Ceylon*, chap. iv.

† Although it is only in the severest cold of winter that the chamois descends to the vicinity of grounds occupied by man, its organization does not confine it to the mountains. In the royal park of Racconigi, on the plain a few miles from Turin, at a height of less than 1,000 feet, is kept a herd of thirty or forty chamois, which thrive and breed apparently as well as in the Alps.

Of course natural reproduction cannot keep pace with this enormous destruction, and many animals of much interest to natural science are in imminent danger of final extirpation.*

Large Marine Animals relatively unimportant in Geography.

Vast as is the bulk of some of the higher orders of aquatic animals, their remains are generally so perishable that, even where most abundant, they do not appear to be now forming permanent deposits of any considerable magnitude; but it is quite otherwise with shell-fish, and, as we shall see hereafter, with many of the minute limeworkers of the sea. There are, on the southern coast of the United States, beds of shells so extensive that they were formerly supposed to have been naturally accumulated, and were appealed to as proofs of an elevation of the coast by geological causes; but they are now ascertained to have been derived chiefly from oysters and other shell-fish, consumed in the course of long ages by the inhabitants of Indian towns. The planting of a bed of oysters in a new locality might very probably lead, in time, to the formation of a bank, which, in connection with other deposits, might perceptibly affect the line of a coast, or, by changing the course of marine currents, or the outlet of a river, produce geographical changes of no small importance.

---

* Objectionable as game laws are, they have done something to prevent the extinction of many quadrupeds, which naturalists would be loth to lose, and, as in the case of the British ox, private parks and preserves have saved other species from destruction. Some few wild animals, such as the American mink, for example, have been protected and bred with profit, and in Pennsylvania an association of gentlemen has set apart, and is about enclosing, a park of 16,000 acres for the breeding of indigenous quadrupeds and fowls.

Introduction and Breeding of Fish.

The introduction and successful breeding of fish of foreign species appears to have been long practised in China, and was not unknown to the Greeks and Romans.* This art has been revived in modern times, but thus far without any important results, economical or physical, though there seems to be good reason to believe it may be employed with advantage on an extended scale. As in the case of plants, man has sometimes undesignedly introduced new species of aquatic animals into countries distant from their birthplace. The accidental escape of the Chinese goldfish from ponds where they were bred as a garden ornament, has peopled some European, and it is said American streams with this species. Canals of navigation and irrigation interchange the fish of lakes and rivers widely separated by natural barriers, as well as the plants which drop their seeds into the waters. The Erie Canal, as measured by its own channel, has a length of about three hundred and sixty miles, and it has ascending and descending locks in both directions. By this route, the fresh-water fish of the Hudson and the Upper Lakes, and some of the indigenous vegetables of these respective basins, have intermixed, and the fauna and flora of the two regions have now more species common to both than before the canal was opened.† The opening of the Suez Canal will, no doubt, produce very interesting revolutions in the animal and vegetable population of both basins. The Mediterranean, with some local exceptions—such as the bays of Calabria, and the coast of Sicily so picturesquely described by

---

* The observations of COLUMELLA, *de Re Rustica*, lib. viii., sixteenth and following chapters, on fish-breeding, are interesting. The Romans not only stocked natural but constructed artificial ponds, of both fresh and salt water, and cut off bays of the sea for this purpose. They also naturalized various species of sea-fish in fresh water.

† The opening or rather the reconstruction of the Claudian emissary by Prince Torlonia, designed to drain the Lake Fucinus, or Celano, has introduced the fish of that lake into the Liri or Garigliano which receives the discharge from the lake.—DOROTEA, *Sommario storico dell' Alieutica*, p. 60.

Quatrefages *—is comparatively poor in marine vegetation, and in shell as well as in fin fish. The scarcity of fish in some of its gulfs is proverbial, and you may scrutinize long stretches of beach on its northern shores, after every south wind for a whole winter, without finding a dozen shells to reward your search. But no one who has not looked down into tropical or subtropical seas can conceive the amazing wealth of the Red Sea in organic life. Its bottom is carpeted or paved with marine plants, with zoöphytes and with shells, while its waters are teeming with infinitely varied forms of moving life. Most of its vegetables and its animals, no doubt, are confined by the laws of their organization to a warmer temperature than that of the Mediterranean, but among them there must be many whose habitat is of a wider range, many whose powers of accommodation would enable them to acclimate themselves in a colder sea.

We may suppose the less numerous aquatic fauna and flora of the Mediterranean to be equally capable of climatic adaptation, and hence there will be a partial interchange of the organic population not already common to both seas. Destructive species, thus newly introduced, may diminish the numbers of their proper prey in either basin, and, on the other hand, the increased supply of appropriate food may greatly multiply the abundance of others, and at the same time add important contributions to the aliment of man in the countries bordering on the Mediterranean.†

Some accidental attraction not unfrequently induces fish to follow a vessel for days in succession, and they may thus be enticed into zones very distant from their native habitat. Several years ago, I was told at Constantinople, upon good authority, that a couple of fish, of a species wholly unknown to

---

* *Souvenirs d'un Naturaliste*, i., pp. 204 *et seqq.*

† The dissolution of the salts in the bed of the Bitter Lakes impregnated the
ter admitted from the Red Sea so highly that for some time fish were not
n that basin. The flow of the current through the canal has now re-
the proportion of saline matter to five per cent., and late travellers
f fish as abundant in its waters.

the natives, had just been taken in the Bosphorus. They were alleged to have followed an English ship from the Thames, and to have been frequently observed by the crew during the passage; but I was unable to learn their specific character.*

Many of the fish which pass the greater part of the year in salt water spawn in fresh, and some fresh-water species, the common brook-trout of New England for instance, which under ordinary circumstances never visit the sea, will, if transferred to brooks emptying directly into the ocean, go down into the salt water after spawning-time, and return again the next season. Some sea fish have been naturalized in fresh water, and naturalists have argued from the character of the fish of Lake Baikal, and especially from the existence of the seal in that locality, that all its inhabitants were originally marine species, and have changed their habits with the gradual conversion of the saline waters of the lake—once, as is assumed, a maritime bay—into fresh.† The presence of the seal is hardly conclusive on this point, for it is sometimes seen in Lake Champlain at the distance of some hundreds of miles from even brackish water. One of these animals was killed on the ice in that lake in February, 1810, another in February, 1846,‡ and remains of the seal have been found at other times in the same waters.

The intentional naturalization of foreign fish, as I have said, has not thus far yielded important fruits; but though this particular branch of what is called, not very happily, *pisciculture*, has not yet established its claims to the attention of the physical geographer or the political economist, the artificial breeding of domestic fish, of the lobster and other crustacea, has already produced very valuable results, and is apparently destined to occupy an extremely conspicuous place in the history of man's efforts to compensate his prodigal waste of the gifts of nature. The arrangements for breeding fish in the Venetian lagoon of Comacchio date far back in the Middle Ages, but the example does not seem to have been followed elsewhere in Europe at that period, except in small ponds where the propagation of the fish was left to nature without much artificial aid. The transplantation of oysters to artificial ponds has long been common, and it appears to have recently succeeded well on a large scale in the open sea on the French coast. A great extension of this fishery is hoped for, and it is now proposed to introduce upon the same coast the American soft clam, which is so abundant in the tide-washed beach sands of Long Island Sound as to form an important article in the diet of the neighboring population. Experimental pisciculture has been highly successful in the United States, and will probably soon become a regular branch of rural industry, especially as Congress, at the session of 1871–2, made liberal provision for its promotion.

---

* Seven or eight years ago, the Italian government imported from France a dredging machine for use in the harbor of La Spezia. The dredge brought attached to its hull a shell-fish not known in Italian waters. The mollusk, finding the local circumstances favorable, established itself in this new habitat, multiplied rapidly, and is now found almost everywhere on the west coast of the Peninsula.

† BABINET, *Études et Lectures*, ii., pp. 108, 110.

‡ THOMPSON, *Natural History of Vermont*, p. 38, and Appendix, p. 13. There is no reason to believe that the seal breeds in Lake Champlain, but the individual last taken there must have been some weeks, at least, in its waters. It was killed on the ice in the widest part of the lake, on the 23d of February, thirteen days after the surface was entirely frozen, except the usual small cracks, and a month or two after the ice closed at all points north of the place where the seal was found.

The restoration of the primitive abundance of salt and fresh water fish, is perhaps the greatest material benefit that, with our present physical resources, governments can hope to confer upon their subjects. The rivers, lakes, and seacoasts once restocked, and protected by law from exhaustion by taking fish at improper seasons, by destructive methods, and in extravagant quantities, would continue indefinitely to furnish a very large supply of most healthful food, which, unlike all domestic and agricultural products, would spontaneously renew itself and cost nothing but the taking. There are many sterile or wornout soils in Europe so situated that they might, at no very formidable cost, be converted into permanent lakes, which would serve not only as reservoirs to retain the water of winter rains and snow, and give it out in the dry season for irrigation, but as breeding ponds for fish, and would thus, without further cost, yield a larger supply of human food than can at present be obtained from them even at a great expenditure of capital and labor in agricultural operations.* The additions which might be made to the nutriment of the civilized world by a judicious administration of the resources of the waters, would allow some restriction of the amount of soil at present employed for agricultural purposes, and a corresponding extension of the area of the forest, and would thus facilitate a return to primitive geographical arrangements which it is important partially to restore.

Destruction of Fish.

The inhabitants of the waters seem comparatively secure from human pursuit or interference by the inaccessibility of their retreats, and by our ignorance of their habits—a natural result of the difficulty of observing the ways of creatures living in a medium in which we cannot exist. Human agency has, nevertheless, both directly and incidentally, produced great changes in the population of the sea, the lakes, and the rivers, and if the effects of such revolutions in aquatic life are apparently of small importance in general geography, they are still not wholly inappreciable. The great diminution in the abundance of the larger fish employed for food or pursued for products useful in the arts is familiar, and when we consider how the vegetable and animal life on which they feed must be effected by the reduction of their numbers, it is easy to see that their destruction may involve considerable modifications in many of the material arrangements of nature. The whale † does not appear to have been an object of pursuit by the ancients, for any pur-

---

* See ACKERHOF, *Die Nutzung der Seiche und Gewässer.* Quedlinburg, 1869.

† I use *whale* not in a technical sense, but as a generic term for all the large inhabitants of the sea popularly grouped under that name.

The Greek κῆτος and the Latin Balæna, though sometimes, especially in pose, nor do we know when the whale fishery first commenced. It was, however, very actively prosecuted in the Middle Ages, and the Biscayans seem to have been particularly successful in this as indeed in other branches of nautical industry.* Five hundred years ago, whales abounded in every sea. They long since became so rare in the Mediterranean as not to afford encouragement for the fishery as a regular occupation; and the great demand for oil and whalebone for mechanical and manufacturing purposes, in the present century, has stimulated the pursuit of the "hugest of living creatures" to such activity, that he has now almost wholly disappeared from many favorite fishing grounds, and in others is greatly diminished in numbers.

---

later classical writers, specifically applied to true cetaceans, were generally much more comprehensive in their signification than the modern word whale. This appears abundantly from the enumeration of the marine animals embraced by Oppian under the name κῆτος, in the first book of the Halieutica.

There is some confusion in Oppian's account of the fishery of the κῆτος in the fifth book of the Halieutica. Part of it is probably to be understood of cetaceans which have *grounded*, as some species often do; but in general it evidently applies to the taking of large fish—sharks, for example, as appears by the description of the teeth—with hook and bait.

* From the narrative of Ohther, introduced by King Alfred into his translation of Orosius, it is clear that the Northmen pursued the whale fishery in the ninth century, and it appears, both from the poem called The Whale, in the Codex Exoniensis, and from the dialogue with the fisherman in the Colloquies of Aelfric, that the Anglo-Saxons followed this dangerous chase at a period not much later. I am not aware of any evidence to show that any of the Latin nations engaged in this fishery until a century or two afterward, though it may not be easy to disprove their earlier participation in it. In mediæval literature, Latin and Romance, very frequent mention is made of a species of vessel called in Latin *baleneria*, *balenerium*, *balenerius*, *balaneria*, etc.; in Catalan, *balener;* in French, *balenier;* all of which words occur in many other forms. The most obvious etymology of these words would suggest the meaning, *whaler*, *baleinier;* but some have supposed that the name was descriptive of the great size of the ships, and others have referred it to a different root. From the fourteenth century, the word occurs oftener, perhaps, in old Catalan, than in any other language; but Capmany does not notice the whale fishery as one of the maritime pursuits of the very enterprising Catalan people, nor do I find any of the products of the whale mentioned in the old Catalan tariffs. The *whalebone* of the mediæval writers, which is described as very white, is doubtless the ivory of the walrus or of the narwhale.

What special functions, besides his uses to man, are assigned to the whale in the economy of nature, we do not know; but some considerations, suggested by the character of the food upon which certain species subsist, deserve to be specially noticed. None of the great mammals grouped under the general name of whale are rapacious. They all live upon small organisms, and the most numerous species feed almost wholly upon the soft gelatinous mollusks in which the sea abounds in all latitudes. We cannot calculate even approximately the number of the whales, or the quantity of organic nutriment consumed by an individual, and of course we can form no estimate of the total amount of animal matter withdrawn by them, in a given period, from the waters of the sea. It is certain, however, that it must have been enormous when they were more abundant, and that it is still very considerable. In 1846 the United States had six hundred and seventy-eight whaling ships chiefly employed in the Pacific, and the product of the American whale fishery for the year ending June 1st, 1860, was seven millions and a half of dollars.* The mere bulk of the whales destroyed in a single

---

* In consequence of the great scarcity of the whale, the use of coal-gas for illumination, the substitution of other fatty and oleaginous substances, such as lard, palm-oil, and petroleum for right-whale oil and spermaceti, the whale fishery has rapidly fallen off within a few years. The great supply of petroleum, which is much used for lubricating machinery as well as for numerous other purposes, has produced a more perceptible effect on the whale fishery than any other single circumstance. According to Bigelow, *Les États-Unis en* 1863, p. 346, the American whaling fleet was diminished by 29 in 1858, 57 in 1860, 94 in 1861, and 65 in 1862. The number of American ships employed in that fishery in 1862 was 353. In 1868, the American whaling fleet was reduced to 223. The product of the whale fishery in that year was 1,485,000 gallons of sperm oil, 2,065,612 gallons of train oil, and 901,000 pounds of whalebone. The yield of the two species of whale is about the same, being estimated at from 4,000 to 5,000 gallons for each fish. Taking the average at 4,500 gallons, the American whalers must have captured 789 whales, besides, doubtless, many which were killed or mortally wounded and not secured. The returns for the year are valued at about five million and a half dollars. Mr. Cutts, from a report by whom most of the above facts are taken, estimates the annual value of the "products of the sea" at $90,000,000.

According to the *New Bedford Standard*, the American whalers numbered year by the American and the European vessels engaged in this fishery would form an island of no inconsiderable dimensions, and each one of those taken must have consumed, in the course of his growth, many times his own weight of mollusks. The destruction of the whales must have been followed by a proportional increase of the organisms they feed upon, and if we had the means of comparing the statistics of these humble forms of life, for even so short a period as that between the years 1760 and 1860, we should find a difference possibly sufficient to suggest an explanation of some phenomena at present unaccounted for.

For instance, as I have observed in another work,* the phosphorescence of the sea was unknown to ancient writers, or at least scarcely noticed by them, and even Homer—who, blind as tradition makes him when he composed his epics, had seen, and marked, in earlier life, all that the glorious nature of the Mediterranean and its coasts discloses to unscientific observation—nowhere alludes to this most beautiful and striking of maritime wonders. In the passage just referred to, I have endeavored to explain the silence of ancient writers with respect to this as well as other remarkable phenomena on psychological grounds; but is it not possible that, in modern times, the animalculæ which produce it may have immensely multiplied, from the destruction of their natural enemies by man, and hence that the gleam shot forth by their decomposition, or by their living processes, is both more frequent and more brilliant than in the days of classic antiquity?

722, measuring 230,218 tons, in 1846. On the 31st December, 1872, the number was reduced to 204, with a tonnage of 47,787 tons, and the importation of whale and sperm oil amounted in that year to 79,000 barrels.

Svend Föyn, an energetic Norwegian, now carries on the whale fishery in the Arctic Ocean in a steamer of 20 horse-power, accompanied by freight-ships for the oil. The whales are killed by explosive shells fired from a small cannon. The number usually killed by Föyn is from 35 to 45 per year.—*The* *erce in the Products of the Sea*, a report by Col. R. D. Cutts, communi- U. S. Senate. Washington, 1872.

in and History of the English Language, &c., pp. 423, 424.

Although the whale does not prey upon smaller creatures resembling himself in form and habits, yet true fishes are extremely voracious, and almost every tribe devours unsparingly the feebler species, and even the spawn and young of its own.[*] The enormous destruction of the shark,[†] the pike, the trout family, and other ravenous fish, as well as of the fishing birds, the seal, and the otter, by man, would naturally have occasioned a great increase in the weaker and more defenceless fish on which they feed, had he not been as hostile to them also as to their persecutors.

Destruction of Aquatic Animals.

It does not seem probable that man, with all his rapacity and all his enginery, will succeed in totally extirpating any salt-water fish, but he has already exterminated at least one marine warm-blooded animal—Steller's sea cow—and the walrus, the sea lion, and other large amphibia, as well as the principal fishing quadrupeds, are in imminent danger of extinction. Steller's sea cow, *Rhytina Stelleri*, was first seen by Europeans in the year 1741, on Bering's Island. It was a huge amphibious mammal, weighing not less than eight thousand pounds, and appears to have been confined exclusively to the islands and coasts in the neighborhood of Bering's Strait. Its flesh was very palatable, and the localities it frequented were easily accessible from the Russian establishments in Kamtschatka. As soon as its existence and character, and the abundance of fur animals in the same waters, were made known to the occupants of those posts by the return of the survivors of Bering's expedition, so active a chase was commenced against the amphibia of that region, that, in the course of twenty-seven years, the sea cow, described by Steller as extremely numerous in 1741, is believed to have been completely extirpated, not a single individual having been seen since the year 1768. The various tribes of seals * in the Northern and Southern Pacific, the walrus † and the sea otter, are already so reduced in numbers that they seem destined soon to follow the sea cow, unless protected by legislation stringent enough, and a police energetic enough, to repress the ardent cupidity of their pursuers.

---

[*] Two young pickerel, *Gystes fasciatus*, five inches long, ate 128 minnows, an inch long, the first day they were fed, 132 the second, and 150 the third. —Fifth *Report of Commissioners of Massachusetts for Introduction of Fish.* 1871, p. 17.

[†] The shark is pursued in all the tropical and subtropical seas for its fins—for which there is a great demand in China as an article of diet—its oil and other products. About 40,000 are taken annually in the Indian Ocean and the contiguous seas. In the North Sea and the Arctic Ocean large numbers are annually caught. See MERK, *Waarenlexikon*—a work of great accuracy and value (Leipzig, 1870), article *Haifisch.*

The seals, the otter tribe, and many other amphibia which feed almost exclusively upon fish, are extremely voracious, and of course their destruction or numerical reduction must have favored the multiplication of the species of fish principally preyed upon by them. I have been assured by the keeper of several young seals that, if supplied at frequent intervals, each seal would devour not less than fourteen pounds of fish, or about a quarter of his own weight, in a day. A very intelligent and observing hunter, who has passed a great part of his life in the forest, after carefully watching the habits of the fresh-water otter of the North American States, estimates their consumption of fish at about four pounds per day.

Man has promoted the multiplication of fish by making war

---

* The most valuable variety of fur seal, formerly abundant in all cold latitudes, is stated to have been completely exterminated in the Southern hemisphere, and to be now found only on one or two small islands of the Aleutian group. In 1867 more than 700,000 seal skins were imported into Great Britain, and at least 600,000 seals are estimated to have been taken in 1870. These numbers do not include the seals killed by the Esquimaux and other rude tribes.

† In 1868, a few American ships engaged in the North Pacific whale fishery turned their attention to the walrus, and took from 200 to 600 each. In 1869 other whalers engaged in the same pursuit, and in 1870 the American fleet is believed to have destroyed not less than fifty thousand of these animals. They yield about twenty gallons of oil and four or five pounds of ivory each.

on their brute enemies, but he has by no means thereby compensated his own greater destructiveness.* The bird and beast of prey, whether on land or in the water, hunt only as long as they feel the stimulus of hunger, their ravages are limited by the demands of present appetite, and they do not wastefully destroy what they cannot consume. Man, on the contrary, angles to-day that he may dine to-morrow; he takes and dries millions of fish on the banks of Newfoundland and the coast of Norway, that the fervent Catholic of the shores of the Mediterranean may have wherewithal to satisfy the cravings of the stomach during next year's Lent, without violating the discipline of the papal church;† and all the arrangements of his fisheries are so organized as to involve the destruction of many more fish than are secured for human use, and the loss of a large proportion of the annual harvest of the sea in the process of curing, or in transportation to the places of its consumption.*

---

* According to Hartwig, the United Provinces of Holland had, in 1618, three thousand herring busses, and nine thousand vessels engaged in the transport of these fish to market. The whole number of persons employed in the Dutch herring fishery was computed at 200,000.

In the latter part of the eighteenth century, this fishery was most successfully prosecuted by the Swedes, and in 1781, the town of Gottenburg alone exported 136,649 barrels, each containing 1,200 herrings, making a total of about 164,000,000; but so rapid was the exhaustion of the fish, from this keen pursuit, that in 1799 it was found necessary to prohibit the exportation of them altogether.—*Das Leben des Meeres*, p. 182.

In 1855, the British fisheries produced 900,000 barrels, or almost enough to supply a fish to every human inhabitant of the globe.

On the shores of Long Island Sound, the white fish, a species of herring too bony to be easily eaten, is used as manure in very great quantities. Ten thousand are employed as a dressing for an acre, and a single net has sometimes taken 200,000 in a day.—DWIGHT'S *Travels*, ii., pp. 512, 515.

The London *Times* of May 11, 1872, informs us that 1,100 tons of mackerel estimated to weigh one pound each had recently been taken in a single night at a fishing station on the British coast.

About ten million eels are sold annually in Billingsgate market, but vastly greater numbers of the young fry, when but three or four inches long, are taken. So abundant are they at the mouths of many French and English rivers, that they are carried into the country by cart-loads, and not only eaten, but given to swine or used as manure.

† The fisheries of Sicily alone are said to yield 20,000 tons of tunny a year. The tunny is principally consumed in Italy during Lent, and a large proportion of the twenty millions of codfish taken annually at the Lofoden fishery on the coast of Norway is exported to the Mediterranean.

Fish are more affected than quadrupeds by slight and even imperceptible differences in their breeding places and feeding grounds. Every river, every brook, every lake stamps a special character upon its salmon, its shad, and its trout, which is at once recognized by those who deal in or consume them. No skill can give the fish fattened by food selected and prepared by man the flavor of those which are nourished at the table of nature, and the trout of the artificial ponds in Germany and Switzerland are so inferior to the brook-fish of the same species and climate, that it is hard to believe them identical. The superior sapidity of the American trout and other fresh-water fishes to the most nearly corresponding European species, which is familiar to every one acquainted with both continents, is probably due less to specific difference than to the fact that, even in the parts of the New World which have been longest cultivated, wild nature is not yet tamed down to the character it has assumed in the Old, and which it will acquire in America also when her civilization shall be as ancient as is now that of Europe.†

---

* According to Berthelot, in the Gulf of Lyons, between Marseilles and the easternmost spur of the Pyrenees, about 5,000,000 small fish are taken annually with the drag-net, and not less than twice as many more, not to speak of spawn, are destroyed by the use of this net.

Between 1861 and 1865 France imported from Norway, for use as bait in the sardine fishery, cod-roes to the value of three million francs.—CUTTS, *Report on Commerce in the Products of the Sea*, 1872, p. 82.

The most reckless waste of aquatic life I remember to have seen noticed, if we except the destruction of herring and other fish with spawn, is that of the eggs of the turtle in the Amazon for the sake of the oil extracted from them. Bates estimates the eggs thus annually sacrificed at 48,000,000.—*Naturalist on the Amazon*, 2d edition, 1864, p. 365.

† It is possible that time may modify the habits of the fresh-water fish of the North American States, and accommodate them to the new physical conditions of their native waters. Hence it may be hoped that nature, even unaided by art, will do something towards restoring the ancient plenty of our lakes and rivers. The decrease of our fresh-water fish cannot be ascribed

Man has hitherto hardly anywhere produced such climatic or other changes as would suffice of themselves totally to banish the wild inhabitants of the dry land, and the disappearance of the native birds and quadrupeds from particular localities is to be ascribed quite as much to his direct persecutions as to the want of forest shelter, of appropriate food, or of other conditions indispensable to their existence. But almost all the processes of agriculture, and of mechanical and chemical industry, are fatally destructive to aquatic animals within reach of their influence. When, in consequence of clearing the woods, the changes already described as thereby produced in the beds and currents of rivers, are in progress, the spawning grounds of fish are exposed from year to year to a succession of mechanical disturbances; the temperature of the water is higher in summer, colder in winter, than when it was shaded and protected by wood; the smaller organisms, which formed the sustenance of the young fry, disappear or are reduced in numbers, and new enemies are added to the old foes that preyed upon them; the increased turbidness of the water in the annual inundations chokes the fish; and, finally, the quickened velocity of its current sweeps them down into the larger rivers or into the sea, before they are yet strong enough to support so great a change of circumstances.* Industrial operations are not less

---

alone to exhaustion by fishing, for in the waters of the valleys and flanks of the Alps, which have been inhabited and fished ten times as long by a denser population, fish are still very abundant, and they thrive and multiply under circumstances where no American species could live at all. On the southern slope of those mountains, trout are caught in great numbers, in the swift streams which rush from the glaciers, and where the water is of icy coldness, and so turbid with particles of fine-ground rock, that you cannot see an inch below the surface. The glacier streams of Switzerland, however, are less abundant in fish.

* A fact mentioned by Schubert—and which in its causes and many of its results corresponds almost precisely with those connected with the escape of Barton Pond in Vermont, so well known to geological students—is important, as showing that the diminution of the fish in rivers exposed to inundations is chiefly to be ascribed to the mechanical action of the current, and not mainly, as some have supposed, to changes of temperature occasioned by clearing.

destructive to fish which live or spawn in fresh water. Mill-dams impede their migrations, if they do not absolutely prevent them, the sawdust from lumber mills clogs their gills, and the thousand deleterious mineral substances, discharged into rivers from metallurgical, chemical, and manufacturing establishments, poison them by shoals.*

We have little evidence that any fish employed as human food has naturally multiplied in modern times, while all the more valuable tribes have been immensely reduced in numbers. This reduction must have affected the more voracious species not used as food by man, and accordingly the shark, and other fish of similar habits, even when not objects of systematic pursuit, are now comparatively rare in many waters where they formerly abounded. The result is, that man has greatly reduced the numbers of all larger marine animals, and consequently indirectly favored the multiplication of the smaller aquatic organisms which entered into their nutriment. This change in the relations of the organic and inorganic matter of the sea must have exercised an influence on the latter. What that influence has been we cannot say, still less can we predict what it will be hereafter; but its action is not for that reason the less certain.†

Our author states that, in 1796, a terrible inundation was produced in the Indalself, which rises in the Storsjö in Jemtland, by drawing off into it the waters of another lake near Ragunda. The flood destroyed houses and fields; much earth was swept into the channel, and the water made turbid and muddy; the salmon and the smaller fish forsook the river altogether, and never returned. The banks of the river have never regained their former solidity, and portions of their soil are still continually falling into the water and destroying its purity.—*Resa genom Sverge*, ii., p. 51.

* The mineral water discharged from a colliery on the river Doon in Scotland discolored the stones in the bed of the river, and killed the fish for twenty miles below.

The fish of the streams in which hemp is macerated in Italy are often poisoned by the juices thus extracted from the plant.—DOROTEA, *Sommario della storia dell' Alieutica*, pp. 64, 65.

† Among the unexpected results of human action, the destruction or multiplication of fish, as well as of other animals, is a not unfrequent occurrence.

Geographical Importance of Birds.

Wild birds form of themselves a very conspicuous and interesting feature in the *staffage*, as painters call it, of the natural landscape, and they are important elements in the view we are taking of geography, whether we consider their immediate or their incidental influence. Birds affect vegetation directly by sowing seeds and by consuming them; they affect it indirectly by destroying insects injurious, or, in some cases, beneficial to vegetable life. Hence, when we kill a seed-sowing bird, we check the dissemination of a plant; when we kill a bird which digests the seed it swallows, we promote the increase of a vegetable. Nature protects the seeds of wild, much more effectually than those of domesticated plants. The cereal grains are completely digested when consumed by birds, but the germ of the smaller stone fruits and of very many other wild vegetables is uninjured, perhaps even stimulated to more vigorous growth, by the natural chemistry of the bird's stomach. The power of flight and the restless habits of the bird enable it to transport heavy seeds to far greater distances than they could be carried by the wind. A swift-winged bird may drop cherry stones a thousand miles from the tree they grow on; a hawk, in tearing

---

Williams, in his *History of Vermont*, i., p. 149, records such a case of the increase of trout. In a pond formed by damming a small stream to obtain water power for a sawmill, and covering one thousand acres of primitive forest, the increased supply of food brought within reach of the fish multiplied them to that degree, that, at the head of the pond, where, in the spring, they crowded together in the brook which supplied it, they were taken by the hands at pleasure, and swine caught them without difficulty. A single sweep of a small scoopnet would bring up half a bushel, carts were filled with them as fast as if picked up on dry land, and in the fishing season they were commonly sold at a shilling (eightpence halfpenny, or about seventeen cents) a bushel. The increase in the size of the trout was as remarkable as the multiplication of their numbers.

The construction of dams and mills is destructive to many fish, but operates as a protection to their prey. The mills on Connecticut River greatly diminished the number of the salmon, but the striped bass, on which the salmon feeds, multiplied in proportion.—DR. DWIGHT, *Travels*, vol. ii., p. 325.

a pigeon, may scatter from its crop the still fresh rice it had swallowed at a distance of ten degrees of latitude, and thus the occurrence of isolated plants in situations where their presence cannot otherwise well be explained, is easily accounted for.* There is a large class of seeds apparently specially fitted by nature for dissemination by animals. I refer to those which attach themselves, by means of hooks, or by viscous juices, to the coats of quadrupeds and the feathers of birds, and are thus transported wherever their living vehicles may chance to wander. Some birds, too, deliberately bury seeds in the earth, or in holes excavated by them in the bark of trees, not indeed with a foresight aiming directly at the propagation of the plant, but from apparently purposeless secretiveness, or as a mode of preserving food for future use.

The tame fowls play a much less conspicuous part in rural life than the quadrupeds, and, in their relations to the economy of nature, they are of very much less moment than four-footed animals, or than the undomesticated birds. The domestic turkey † is probably more numerous in the territory of the United States than the wild bird of the same species ever was, and the grouse cannot, at the period of their greatest abundance, have counted as many as we now number of the common hen. The dove, however, must fall greatly short of the wild pigeon in multitude, and it is hardly probable that the flocks of domestic geese and ducks are as numerous as once were those of their wild congeners. The pigeon, indeed, seems to have multiplied immensely, for some years after the first clearings in the woods, because the settlers warred unsparingly upon the hawk, while the crops of grain and other vegetable growths increased the supply of food within the reach of the young birds, at the age when their power of flight is not yet great enough to enable them to seek it over a wide area.* The pigeon is not described by the earliest white inhabitants of the American States as filling the air with such clouds of winged life as astonished naturalists in the descriptions of Audubon, and, at the present day, the net and the gun have so reduced its abundance, that its appearance in large numbers is recorded only at long intervals, and it is never seen in the great flocks remembered by many still living observers as formerly very common.

---

* Pigeons were shot near Albany, in New York, a few years ago, with green rice in their crops, which it was thought must have been growing, a very few hours before, at the distance of seven or eight hundred miles. The efforts of the Dutch to confine the cultivation of the nutmeg to the island of Banda are said to have been defeated by the birds, which transported this heavy fruit to other islands.

† The wild turkey takes readily to the water, and is able to cross rivers of very considerable width by swimming. By way of giving me an idea of the former abundance of this bird, an old and highly respectable gentleman who was among the early white settlers of the West, told me that he once counted, in walking down the northern bank of the Ohio River, within a distance of four miles, eighty-four turkeys as they landed singly, or at most in pairs, after swimming over from the Kentucky side

Introduction of Birds.

Man has undesignedly introduced into new districts perhaps fewer species of birds than of quadrupeds; † but the distribution of birds is very much influenced by the character of his industry, and the transplantation of every object of agricultural production is, at a longer or shorter interval, followed by that of the birds which feed upon its seeds, or more frequently upon the insects it harbors. The vulture, the crow, and other winged scavengers, follow the march of armies as regularly as the wolf. Birds accompany ships on long voyages, for the sake of the offal which is thrown overboard, and, in such cases, it might often happen that they would breed and become naturalized in countries where they had been unknown before.* There is a familiar story of an English bird which built its nest in an unused block in the rigging of a ship, and made one or two short voyages with the vessel while hatching its eggs. Had the young become fledged while lying in a foreign harbor, they would of course have claimed the rights of citizenship in the country where they first took to the wing.†

---

* The wood-pigeon, as well as the domestic dove, has been observed to increase in numbers in Europe also, when pains have been taken to exterminate the hawk. The American pigeons, which migrated in flocks so numerous that they were whole days in passing a given point, were no doubt injurious to the grain, but probably less so than is generally supposed; for they did not confine themselves exclusively to the harvests for their nourishment.

† The first mention I have found of the naturalization of a wild bird in modern Europe is in the *Menagiana*, vol. iii., p. 174, edition of 1715, where it is stated that René, King of Sicily and Duke of Anjou, who died in 1480, introduced the red-legged partridge into the latter country. Attempts have been made, and I believe with success, to naturalize the European lark on Long Island, and the English sparrow has been introduced into various parts of the Northern States, where he is useful by destroying noxious insects and worms not preyed upon by native birds.

The humming-bird has resisted all efforts to acclimate him in Europe, though they have not unfrequently survived the passage across the ocean.

In Switzerland and some other parts of Europe the multiplication of insectivorous birds is encouraged by building nests for them, and it is alleged that both fruit and forest trees have been essentially benefited by the protection thus afforded them.

---

* Gulls hover about ships in port, and often far out at sea, diligently watching for the waste of the caboose. While the four great fleets, English, French, Turkish, and Egyptian, were lying in the Bosphorus, in the summer and autumn of 1853, a young lady of my family called my attention to the fact that the gulls were far more numerous about the ships of one of the fleets than about the others. This was verified by repeated observation, and the difference was owing no doubt to the greater abundance of the refuse from the cookrooms of the naval squadron most frequented by the birds. Persons acquainted with the economy of the navies of the states in question, will be able to conjecture which fleet was most favored with these delicate attentions. The American gull follows the steamers up the Mississippi, and has been shot 1,500 miles from the sea.

† Birds do not often voluntarily take passage on board ships bound for foreign countries, but I can testify to one such case. A stork, which had nested near one of the palaces on the Bosphorus, had, by some accident, injured a wing, and was unable to join his fellows when they commenced their winter migration to the banks of the Nile. Before he was able to fly again, he was caught, and the flag of the nation to which the palace belonged was tied to his leg, so that he was easily identified at a considerable distance. As his wing grew stronger, he made several unsatisfactory experiments at flight, and at last, by a vigorous effort, succeeded in reaching a passing ship bound southward, and perched himself on a topsail-yard. I happened to witness this movement, and observed him quietly maintaining his position as long as I could discern him with a spy-glass. I supposed he finished the voyage, for he certainly did not return to the palace.

An unfortunate popular error greatly magnifies the injury done to the crops of grain and leguminous vegetables by wild birds. Very many of those generally supposed to consume large quantities of the seeds of cultivated plants really feed almost exclusively upon insects, and frequent the wheatfields, not for the sake of the grain, but for the eggs, larvæ, and fly of the multiplied tribes of insect life which are so destructive to the harvests. This fact has been so well established by the examination of the stomachs of great numbers of birds in Europe and the United States, at different seasons of the year, that it is no longer open to doubt, and it appears highly probable that even the species which consume more or less grain generally make amends by destroying insects whose ravages would have been still more injurious.* On this subject, we

---

* Even the common crow has found apologists, and it has been asserted that he pays for the Indian corn he consumes by destroying the worms and larvæ which infest that plant.

Professor Treadwell, of Massachusetts, found that a half-grown American robin in confinement ate in one day sixty-eight worms, weighing together nearly once and a half as much as the bird himself, and another had previously starved upon a daily allowance of eight or ten worms, or about twenty per cent. of his own weight. The largest of these numbers appeared, so far as could be judged by watching parent birds of the same species, as they brought food to their young, to be much greater than that supplied to them when fed in the nest; for the old birds did not return with worms or insects oftener than once in ten minutes on an average. If we suppose the parents to hunt for food twelve hours in a day, and a nest to contain four young, we should have seventy-two worms, or eighteen each, as the daily supply of the brood. It is probable enough that some of the food collected by the parents may be more nutritious than the earthworms, and consequently that a smaller quantity sufficed for the young in the nest than when reared under artificial conditions.

The supply required by growing birds is not the measure of their wants after they have arrived at maturity, and it is not by any means certain that great muscular exertion always increases the demand for nourishment, either in the lower animals or in man. The members of the English Alpine Club are not distinguished for appetites which would make them unwelcome guests to Swiss landlords, and I think every man who has had the personal charge of field or railway hands, must have observed that laborers who spare their strength the least are not the most valiant trencher champions. During the period when imprisonment for debt was permitted in New England, persons confined in country jails had no specific allowance, and they were com-have much other evidence besides that derived from dissection. Direct observation has shown, in many instances, that the destruction of wild birds has been followed by a great multiplication of noxious insects, and, on the other hand, that these latter have been much reduced in numbers by the protection and increase of the birds that devour them. Many interesting facts of this nature have been collected by professed naturalists, but I shall content myself with a few taken from familiar and generally accessible sources. The following extract is from Michelet, *L'Oiseau*, pp. 169, 170:

"The *stingy* farmer—an epithet justly and feelingly bestowed by Virgil. Avaricious, blind, indeed, who proscribes the birds—those destroyers of insects, those defenders of his harvests. Not a grain for the creature which, during the rains of winter, hunts the future insect, finds out the nests of the larvæ, examines, turns over every leaf, and destroys, every day, thousands of incipient caterpillars. But sacks of corn for the mature insect, whole fields for the grasshoppers, which the bird would have made war upon. With eyes fixed upon his furrow, upon the present moment only, without seeing and without foreseeing, blind to the great harmony which is never broken with impunity, he has everywhere demanded or approved laws for the extermination of that necessary ally of his toil—the insectivorous bird. And the insect has well avenged the bird. It has become necessary to revoke in haste the proscription. In the Isle of Bourbon, for instance, a price was set on the head of the martin; it disappeared, and the grasshoppers took possession of the island, devouring, withering, scorching with a biting drought all that they did not consume. In North America it has been the same with the starling, the protector of Indian corn.* Even the sparrow, which really

---

monly fed without stint. I have often inquired concerning their diet, and been assured by the jailers that their prisoners, who were not provided with work or other means of exercise, consumed a considerably larger supply of food than common out-door laborers.

* I hope Michelet has good authority for this statement, but I am unable to confirm it.

does attack grain, but which protects it still more, the pilferer, the outlaw, loaded with abuse and smitten with curses—it has been found in Hungary that they were likely to perish without him, that he alone could sustain the mighty war against the beetles and the thousand winged enemies that swarm in the lowlands; they have revoked the decree of banishment, recalled in haste this valiant militia, which, though deficient in discipline, is nevertheless the salvation of the country.*

"Not long since, in the neighborhood of Rouen and in the valley of Monville, the blackbird was for some time proscribed. The beetles profited well by this proscription; their larvæ, infinitely multiplied, carried on their subterranean labors with such success, that a meadow was shown me, the surface of which was completely dried up, every herbaceous root was consumed, and the whole grassy mantle, easily loosened, might have been rolled up and carried away like a carpet."

The general hostility of the European populace to the smaller birds is, in part, the remote effect of the reaction created by the game laws. When the restrictions imposed upon the chase by those laws were suddenly removed in France, the whole people at once commenced a destructive campaign against every species of wild animal. Arthur Young, writing in Provence, on the 30th of August, 1789, soon after the National Assembly had declared the chase free, thus complains of the annoyance he experienced from the use made by the peasantry of their newly-won liberty. "One would think that every rusty firelock in all Provence was at work in the indiscriminate destruction of all the birds. The wadding buzzed by my ears, or fell into my carriage, five or six times in the course of the day." * * "The declaration of the Assembly that every man is free to hunt on his own land * * has filled all France with an intolerable cloud of sportsmen. * * The declaration speaks of compensations and indemnities [to the *seigneurs*], but the ungovernable populace takes advantage of the abolition of the game laws and laughs at the obligation imposed by the decree."

---

* Apropos of the sparrow—a single pair of which, according to Michelet, p. 315, carries to the nest four thousand and three hundred caterpillars or coleoptera in a week—I find in an English newspaper a report of a meeting of a "Sparrow Club," stating that the member who took the first prize had destroyed 1,467 of these birds within the year, and that the prowess of the other members had brought the total number up to 11,944 birds, besides 2,556 eggs. Every one of the fourteen thousand hatched and unhatched birds, thus sacrificed to puerile vanity and ignorant prejudice, would have saved his bushel of wheat by preying upon insects that destroy the grain.

The contagious influence of the French Revolution occasioned the removal of similar restrictions, with similar results, in other countries. The habits then formed have become hereditary on the Continent, and though game laws still exist in England, there is little doubt that the blind prejudices of the ignorant and half-educated classes in that country against birds are, in some degree, at least, due to a legislation, which, by restricting the chase of game worth killing, drives the unprivileged sportsman to indemnify himself by slaughtering all wild life which is not reserved for the amusement of his betters. Hence the lord of the manor buys his partridges and his hares by sacrificing the bread of his tenants, and so long as the members of "Sparrow Clubs" are forbidden to follow higher game, they will suicidally revenge themselves by destroying the birds which protect their wheatfields.

On the Continent, and especially in Italy, the comparative scarcity and dearness of animal food combine with the feeling I have just mentioned to stimulate still further the destructive passions of the fowler. In the Tuscan province of Grosseto, containing less than 2,000 square miles, nearly 300,000 thrushes and other small birds are annually brought to market.*

---

* SALVAGNOLI, *Memorie sulle Maremme Toscane*, p. 143. The country about Naples is filled with slender towers fifteen or twenty feet high, which are a standing puzzle to strangers. They are the stations of the fowlers who watch from them the flocks of small birds and drive them down into the nets by throwing stones over them.

In Northern and Central Italy, one often sees hillocks crowned with grove-like plantations of small trees, much resembling large arbors. These serve to collect birds, which are entrapped in nets in great numbers. These plan-

Birds are less hardy in constitution, they possess less facility of accommodation,* and they are more severely affected by

---

tations are called *ragnaje*, and the reader will find, in Bindi's edition of Davanzati, a very pleasant description of a ragnaja, though its authorship is not now ascribed to that eminent writer.

Tschudi has collected in his little work, *Ueber die Landwirthschaftliche Bedeutung der Vögel*, many interesting facts respecting the utility of birds, and the wanton destruction of them in Italy and elsewhere. Not only the owl, but many other birds more familiarly known as predacious in their habits, are useful by destroying great numbers of mice and moles. The importance of this last service becomes strikingly apparent when it is known that the burrows of the moles are among the most frequent causes of rupture in the dikes of the Po, and, consequently, of inundations which lay many square miles of land under water. See *Annales des Ponts et Chaussées*, 1847, 1^{ere} sémestre, p. 150; VOGT, *Nützliche und schädliche Thiere;* and particularly articles in the *Giornale del Club Alpino*, vol. iv., no. 15, and vol. v., no. 16.

See also in *Aus der Natur*, vol. 54, p. 797, an article entitled *Nutzen der Vögel für die Landwirthschaft*, where it is affirmed that "without birds no agriculture or even vegetation would be possible."

In an interesting memoir by Rondani, published in the *Bollettino del Comizio agrario di Parma* for December, 1868, it is maintained that birds are often injurious to the agriculturist, by preying not only on noxious insects, but sometimes exclusively, or at least by preference, on entomophagous tribes which would otherwise destroy those injurious to cultivated plants. See also articles by Prof. Sabbioni in the *Giornale di Agricoltura di Bologna*, November and December, 1870, and other articles in the same journal of 15th and 30th April, 1870.

* Wild birds are very tenacious in their habits. The extension of particular branches of agriculture introduces new birds; but unless in the case of such changes in physical conditions, particular species seem indissolubly attached to particular localities. The migrating tribes follow almost undeviatingly the same precise line of flight in their annual journeys, and establish themselves in the same breeding-places from year to year. The stork is a strong-winged bird and roves far for food, but very rarely establishes new colonies. He is common in Holland, but unknown in England. Not above five or six pairs of storks commonly breed in the suburbs of Constantinople along the European shore of the narrow Bosphorus, while—much to the satisfaction of the Moslems, who are justly proud of the marked partiality of so orthodox a bird—dozens of chimneys of the true believers on the Asiatic side are crowned with his nests.

The appearance of the dove-like grouse, *Tetrao paradoxus*, or *Syrrhaptes Pallasii*, in various parts of Europe, in 1859 and the following years, is a climatic excess than quadrupeds. Besides, they generally want the special means of shelter against the inclemency of the weather and against pursuit by their enemies, which holes and dens afford to burrowing animals and to some larger beasts of prey. The egg is exposed to many dangers before hatching, and the young bird is especially tender, defenceless, and helpless. Every cold rain, every violent wind, every hailstorm during the breeding season, destroys hundreds of nestlings, and the parent often perishes with her progeny while brooding over it in the vain effort to protect it.* The great proportional numbers of birds, their migratory habits, and the ease with which by their power of flight they may escape most dangers that beset them, would seem to secure them from extirpation, and even from very great numerical reduction. But experience shows that when not protected by law, by popular favor or superstition, or by other special circumstances, they yield very readily to the hostile influences of civilization, and, though the first operations of the settler are favorable to the increase of many species, the great extension of rural and of mechanical

---

noticeable exception to the law of regularity which seems to govern the movements and determine the habitat of birds. The proper home of this bird is the steppes of Tartary, and it is not recorded to have been observed in Europe, or at least west of Russia, until the year above mentioned, when many flocks of twenty or thirty, and even a hundred individuals, were seen in Bohemia, Germany, Holland, Denmark, England, Ireland, and France. A considerable flock frequented the Frisian island of Borkum for more than five months. It was hoped they would breed and remain permanently in the island, but this expectation has been disappointed, and the steppe-grouse seems to have disappeared again altogether.

* It is not the unfledged and the nursing bird alone that are exposed to destruction by severe weather. Whole flocks of adult and strong-winged tribes are killed by hail. Severe winters are usually followed by a sensible diminution in the numbers of the non-migrating birds, and a cold storm in summer often proves fatal to the more delicate species. On the 10th of June, 184–, five or six inches of snow fell in Northern Vermont. The next morning I found a humming-bird killed by the cold, and hanging by its claws just below a loose clapboard on the wall of a small wooden building where it had sought shelter.

industry is, in a variety of ways, destructive even to tribes not directly warred upon by man.*

Nature sets bounds to the disproportionate increase of birds, while at the same time, by the multitude of their resources, she secures them from extinction through her own spontaneous agencies. Man both preys upon them and wantonly destroys

---

* LYELL, *Antiquity of Man*, p. 409, observes: "Of birds it is estimated that the number of those which die every year equals the aggregate number by which the species to which they respectively belong is, on the average, permanently represented."

A remarkable instance of the influence of new circumstances upon birds was observed upon the establishment of a light-house on Cape Cod some years since. The morning after the lamps were lighted for the first time, more than a hundred dead birds of several different species, chiefly water-fowl, were found at the foot of the tower. They had been killed in the course of the night by flying against the thick glass or grating of the lantern.

From an article by A. Esquiros, in the *Revue des Deux Mondes* for Sept. 1, 1864, entitled, *La vie Anglaise*, p. 119, it appears that such occurrences as that stated in the note have been not unfrequent on the British coast. Are the birds thus attracted by new lights, flocks in migration?

Migrating birds, whether for greater security from eagles, hawks, and other enemies, or for some unknown reason, perform a great part of their annual journeys by night; and it is observed in the Alps that they follow the high roads in their passage across the mountains. This is partly because the food in search of which they must sometimes descend is principally found near the roads. It is, however, not altogether for the sake of consorting with man, or of profiting by his labors, that their line of flight conforms to the paths he has traced, but rather because the great roads are carried through the natural depressions in the chain, and hence the birds can cross the summit by these routes without rising to a height where at the seasons of migration the cold would be excessive.

The instinct which guides migratory birds in their course is not in all cases infallible, and it seems to be confounded by changes in the condition of the surface. I am familiar with a village in New England, at the junction of two valleys, each drained by a mill-stream, where the flocks of wild geese which formerly passed, every spring and autumn, were very frequently lost, as it as popularly phrased, and I have often heard their screams in the night as they flew wildly about in perplexity as to the proper course. Perhaps the village lights embarrassed them, or perhaps the constant changes in the face of the country, from the clearings then going on, introduced into the landscape features not according with the ideal map handed down in the anserine family, and thus deranged its traditional geography.

The modern increased facilities of transportation have brought distant markets within reach of the professional hunter, and thereby given a new impulse to his destructive propensities. Not only do all Great Britain and Ireland contribute to the supply of game for the British capital, but the canvas-back duck of the Potomac, and even the prairie hen from the basin of the Mississippi, may be found at the stalls of the London poulterer. Kohl * informs us that on the coasts of the North Sea, twenty thousand wild ducks are usually taken in the course of the season in a single decoy, and sent to the large maritime towns for sale. The statistics of the great European cities show a prodigious consumption of game-birds, but the official returns fall far below the truth, because they do not include the rural districts, and because neither the poacher nor his customers report the number of his victims. Reproduction, in cultivated countries, cannot keep pace with this excessive destruction, and there is no doubt that all the wild birds which are chased for their flesh or their plumage are diminishing with a rapidity which justifies the fear that the last of them will soon follow the dodo and the wingless auk.

Fortunately the larger birds which are pursued for their flesh or for their feathers, and those the eggs of which are used as food, are, so far as we know the functions appointed to them by nature, not otherwise specially useful to man, and, therefore, their wholesale destruction is an economical evil only in the same sense in which all waste of productive capital is an evil.† If it were possible to confine the consumption of game-fowl to a number equal to the annual increase, the world would be a gainer, but not to the same extent as it would be by

---

* *Die Herzogthümer Schleswig und Holstein*, i., p. 203.

† The increased demand for animal oils for the use of the leather-dresser is now threatening the penguin with the fate of the wingless auk. According to the *Report of the Agricultural Department of the U. S.* for August and September, 1871, p. 340, small vessels are fitted out for the chase of this bird, and return from a six weeks' cruise with 25,000 or 30,000 gallons of oil. About eleven birds are required for a gallon, and consequently the vessels take upon an average 300,000 penguins each.

checking the wanton sacrifice of millions of the smaller birds, which are of no real value as food, but which, as we have seen, render a most important service by battling, in our behalf, as well as in their own, against the countless legions of humming and of creeping things, with which the prolific powers of insect life would otherwise cover the earth.

Utility and Destruction of Reptiles.

The disgust and fear with which the serpent is so universally regarded expose him to constant persecution by man, and perhaps no other animal is so relentlessly sacrificed by him. Nevertheless, snakes as well as lizards and other reptiles are not wholly useless to their great enemy. The most formidable foes of the insect, and even of the small rodents, are the reptiles. The chameleon approaches the insect perched upon the twig of a tree, with an almost imperceptible slowness of motion, until, at the distance of a foot, he shoots out his long, slimy tongue, and rarely fails to secure the victim. Even the slow toad catches the swift and wary housefly in the same manner; and in the warm countries of Europe, the numerous lizards contribute very essentially to the reduction of the insect population, which they both surprise in the winged state upon walls and trees, and consume as egg, worm, and chrysalis, in their earlier metamorphoses. The serpents feed much upon insects, as well as upon mice, moles, and small reptiles, including also other snakes.

In temperate climates, snakes are consumed by scarcely any beast or bird of prey except the stork, and they have few dangerous enemies but man, though in the tropics other animals prey upon them.* It is doubtful whether any species of serpent has been exterminated within the human period, and even the dense population of China has not been able completely to rid itself of the viper. They have, however, almost entirely disappeared from particular localities. The rattlesnake is now wholly unknown in many large districts where it was extremely common half a century ago, and Palestine has long been, if not absolutely free from venomous serpents, at least very nearly so.[*]

---

* It is very questionable whether there is any foundation for the popular belief in the hostility of swine and of deer to the rattlesnake, and careful experiments as to the former quadruped seem to show that the supposed enmity is wholly imaginary. It is however affirmed in an article in *Nature*, June 11, 1872, p. 215, that the pigs have exterminated the rattlesnake in some parts of Oregon, and that swine are destructive to the cobra de capello in India. Observing that the starlings, *stornelli*, which bred in an old tower in

---

Piedmont, carried something from their nests and dropped it upon the ground about as often as they brought food to their young, I watched their proceedings, and found every day lying near the tower numbers of dead or dying slowworms, and, in a few cases, small lizards, which had, in every instance, lost about two inches of the tail. This part I believe the starlings gave to their nestlings, and threw away the remainder.

[*] Russell denies the existence of poisonous snakes in Northern Syria, and states that the last instance of death known to have occurred from the bite of a serpent near Aleppo took place a hundred years before his time. In Palestine, the climate, the thinness of population, the multitude of insects and of lizards, all circumstances, in fact, seem very favorable to the multiplication of serpents, but the venomous species, at least, are extremely rare, if at all known, in that country. I have, however, been assured by persons very familiar with Mount Lebanon, that cases of poisoning from the bite of snakes had occurred within a few years, near Hasbeiyeh, and at other places on the southern declivities of Lebanon and Hermon. In Egypt, on the other hand, the cobra, the asp, and the cerastes are as numerous as ever, and are much dreaded by all the natives except the professional snake charmers.

The recent great multiplication of vipers in some parts of France is a singular and startling fact. Toussenel, quoting from official documents, states, that upon the offer of a reward of fifty centimes, or ten cents, a head, *twelve thousand* vipers were brought to the prefect of a single department, and that in 1859 fifteen hundred snakes and twenty quarts of snakes' eggs were found under a farm-house hearthstone. The granary, the stables, the roof, the very beds swarmed with serpents, and the family were obliged to abandon its habitation. Dr. Viaugrandmarais, of Nantes, reported to the prefect of his department more than two hundred recent cases of viper bites, twenty-four of which proved fatal.—*Tristia*, p. 176 *et seqq.* According to the *Journal des Débats* for Oct. 1st, 1867, the Department of the Côte d'Or paid in the year 1866 eighteen thousand francs for the destruction of vipers. The reward was thirty centimes a head, and consequently the number killed was about sixty thousand. A friend residing in that department informs me that it was strongly suspected that many of these snakes were imported from other departments for the sake of the premium.

In *Nature* for 1870 and 1871 we are told that the number of deaths from the

The serpent does not appear to have any natural limit of growth, and we are therefore not authorized wholly to discredit the evidence of ancient naturalists in regard to the extraordinary dimensions which these reptiles are said by them to have sometimes attained. The use of firearms has enabled man to reduce the numbers of the larger serpents, and they do not often escape him long enough to arrive at the size ascribed to them by travellers a century or two ago. Captain Speke, however, shot a serpent in Africa which measured fifty-one and a half feet in length.

Some enthusiastic entomologist will, perhaps, by and by discover that insects and worms are as essential as the larger organisms to the proper working of the great terraqueous machine, and we shall have as eloquent pleas in defence of the mosquito, and perhaps even of the tzetze-fly, as Toussenel and Michelet have framed in behalf of the bird. The silkworm, the lac insect, and the bee need no apologist; a gallnut produced by the puncture of a *cynips* on a Syrian oak is a necessary ingredient in the ink I am writing with, and from my windows I recognize the grain of the kermes and the cochineal in the gay habiliments of the holiday groups beneath them.

These humble forms of being are seldom conspicuous by mere mass, and though the winds and the waters sometimes sweep together large heaps of locusts and even of may-flies, their remains are speedily decomposed, their exuviæ and their structures form no strata, and still less does nature use them, as she does the calcareous and silicious cases and dwellings of animalcular species, to build reefs and spread out submarine deposits, which subsequent geological action may convert into islands and even mountains.*

---

bites of venomous serpents in the Bengal Presidency, in the year 1869, was 11,416, and that in the whole of British India not less than 40,000 human lives are annually lost from this cause. In one small department, a reward of from three to six pence a head for poisonous serpents brought in 1,200 a day, and in two months the government paid £10,000 sterling for their destruction.

* Although the remains of extant animals are rarely, if ever, gathered in sufficient quantities to possess any geographical importance by their mere

But the action of the creeping and swarming things of the earth, though often passed unnoticed, is not without important effects in the general economy of nature. The geographical importance of insects proper, as well as of worms, depends principally on their connection with vegetable life as agents of its fecundation, and of its destruction. We learn from Darwin, "On Various Contrivances by which British and Foreign Orchids are Fertilized by Insects," that some six thousand species of orchids are absolutely dependent upon the agency of insects for their fertilization, and that consequently, were those plants unvisited by insects, they would all rapidly disappear. What is true of the orchids is more or less true of many other vegetable families.* We do not know the limits of this agency, and

---

mass, the decayed exuviæ of even the smaller and humbler forms of life are sometimes abundant enough to exercise a perceptible influence on soil and atmosphere. "The plain of Cumana," says Humboldt, "presents a remarkable phenomenon, after heavy rains. The moistened earth, when heated by the rays of the sun, diffuses the musky odor common in the torrid zone to animals of very different classes, to the jaguar, the small species of tiger-cat, the cabiaï, the gallinazo vulture, the crocodile, the viper, and the rattlesnake. The gaseous emanations, the vehicles of this aroma, appear to be disengaged in proportion as the soil, which contains the remains of an innumerable multitude of reptiles, worms, and insects, begins to be impregnated with water. Wherever we stir the earth, we are struck with the mass of organic substances which in turn are developed and become transformed or decomposed. Nature in these climes seems more active, more prolific, and, so to speak, more prodigal of life."

* Later observations of Darwin and other naturalists have greatly raised former estimates of the importance of insect life in the fecundation of plants, and among other remarkable discoveries it has been found that, in many cases at least, insects are necessary even to monœcious vegetables, because the male flower does not impregnate the female growing on the same stem, and the latter can be fecundated only by pollen supplied to it by insects from another plant of the same species.

"Who would ever have thought," says Preyer, "that the abundance and beauty of the pansy and of the clover were dependent upon the number of cats and owls? But so it is. The clover and the pansy cannot exist without the humble-bee, which, in search of his vegetable nectar, transports unconsciously the pollen from the masculine to the feminine flower, a service which other insects perform only partially for these plants. Their existence therefore depends upon that of the humble-bee. The mice make war upon this many of the insects habitually regarded as unqualified pests, may directly or indirectly perform functions as important to the most valuable plants as the services rendered by certain tribes to the orchids. I say directly or indirectly, because, besides the other arrangements of nature for checking the undue multiplication of particular species, she has established a police among insects themselves, by which some of them keep down or promote the increase of others; for there are insects, as well as birds and beasts, of prey. The existence of an insect which fertilizes a useful vegetable may depend on that of another insect which constitutes his food in some stage of his life, and this other again may be as injurious to some plant as his destroyer is to a different species.

The ancients, according to Pliny, were accustomed to hang branches of the wild fig upon the domestic tree, in order that the insects which frequented the former might hasten the ripening of the cultivated fig by their punctures—or, as others suppose, might fructify it by transporting to it the pollen of the wild fruit—and this process, called caprification, is not yet entirely obsolete.*

The perforations of the earthworms and of many insect larvæ mechanically affect the texture of the soil and its permeability by water, and they therefore have a certain influence on the form and character of terrestrial surface. The earthworms

---

bee. In their fondness for honey they destroy the nest and at the same time the bee. The principal enemies of mice are cats and owls, and therefore the finest clovers and the most beautiful pansies are found near villages where cats and owls abound."—PREYER, *Der Kampf um das Dasein*, p. 22. See also DELPINO, *Pensieri sulla biologia vegetale*, and other works of the same able observer on vegetable physiology.

* The utility of caprification has been a good deal disputed, and it has, I believe, been generally abandoned in Italy, though still practised in Greece. See BROWNE, *The Trees of America*, p. 475, and on caprification in Kabylia, N. BIBESCO, *Les Kabyles du Djurdjura*, in *Revue des Deux Mondes* for April 1st, 1865, p. 589; also, *Aus der Natur*, vol. xxx., p. 684, and PHIPSON, *Utilization of Minute Life*, p. 59. In some parts of Sicily, sprigs of mint, *mentha pulegium*, are used instead of branches of the wild fig for caprification. PITRÈ, *Usi popolari Siciliani*, 1871, p. 18.

long ago made good their title to the respect and gratitude of the farmer as well as of the angler. Their utility has been pointed out in many scientific as well as in many agricultural treatises. The following extract from an essay on this subject will answer my present purpose:

"Worms are great assistants to the drainer, and valuable aids to the farmer in keeping up the fertility of the soil. They love moist, but not wet soils; they will bore down to, but not into water; they multiply rapidly on land after drainage, and prefer a deeply-dried soil. On examining part of a field which had been deeply drained, after long-previous shallow drainage, it was found that the worms had greatly increased in number, and that their bores descended quite to the level of the pipes. Many worm-bores were large enough to receive the little finger. A piece of land near the sea in Lincolnshire, over which the sea had broken and killed all the worms, remained sterile until the worms again inhabited it. A piece of pasture land, in which worms were in such numbers that it was thought their casts interfered too much with its produce, was rolled at night in order to destroy the worms. The result was, that the fertility of the field greatly declined, nor was it restored until they had recruited their numbers, which was aided by collecting and transporting multitudes of worms from the fields.

"The great depth into which worms will bore, and from which they push up fine fertile soil, and cast it on the surface, have been well shown by the fact that in a few years they have actually elevated the surface of fields by a large layer of rich mould, several inches thick, thus affording nourishment to the roots of grasses, and increasing the productiveness of the soil."

It should be added that the writer quoted, and all others who have discussed the subject, have, so far as I know, overlooked one very important element in the fertilization produced by earthworms. I refer to the enrichment of the soil by their excreta during life, and by the decomposition of their remains when they die. The manure thus furnished is as valuable as the like amount of similar animal products derived from higher organisms, and when we consider the prodigious numbers of these worms found on a single square yard of some soils, we may easily see that they furnish no insignificant contribution to the nutritive material required for the growth of plants.*

The carnivorous and often herbivorous insects render another important service to man by consuming dead and decaying animal and vegetable matter, the decomposition of which would otherwise fill the air with effluvia noxious to health. Some of them, the grave-digger beetle, for instance, bury the small animals in which they lay their eggs, and thereby prevent the escape of the gases disengaged by putrefaction. The prodigious rapidity of development in insect life, the great numbers of the individuals in many species, and the voracity of most of them while in the larva state, justify the appellation of nature's scavengers which has been bestowed upon them, and there is very little doubt that, in warm countries, they consume a larger quantity of putrescent organic matter than the quadrupeds and birds which feed upon such aliment.

---

* I believe there is no foundation for the supposition that earthworms attack the tuber of the potato. Some of them, especially one or two species employed by anglers as bait, if natives of the woods, are at least rare in shaded grounds, but multiply very rapidly after the soil is brought under cultivation. Forty or fifty years ago they were so scarce in the newer parts of New England, that the rustic fishermen of every village kept secret the few places where they were to be found in their neighborhood, as a professional mystery, but at present one can hardly turn over a shovelful of rich moist soil anywhere, without unearthing several of them. A very intelligent lady, born in the woods of Northern New England, told me that, in her childhood, these worms were almost unknown in that region, though anxiously sought for by the anglers, but that they increased as the country was cleared, and at last became so numerous in some places, that the water of springs, and even of shallow wells, which had formerly been excellent, was rendered undrinkable by the quantity of dead worms that fell into them. The increase of the robin and other small birds which follow the settler when he has prepared a suitable home for them, at last checked the excessive multiplication of the worms, and abated the nuisance.

Introduction of Insects.

The general tendency of man's encroachments upon spontaneous nature has been to increase insect life at the expense of vegetation and of the smaller quadrupeds and birds. Doubtless there are insects in all woods, but in temperate climates they are comparatively few and harmless, and the most numerous tribes which breed in the forest, or rather in its waters, and indeed in all solitudes, are those which little injure vegetation, such as mosquitoes, gnats, and the like. With the cultivated plants of man come the myriad tribes which feed or breed upon them, and agriculture not only introduces new species, but so multiplies the number of individuals as to defy calculation. Newly introduced vegetables frequently escape for years the insect plagues which had infested them in their native habitat; but the importation of other varieties of the plant, the exchange of seed, or some mere accident, is sure in the long run to carry the egg, the larva, or the chrysalis to the most distant shores where the plant assigned to it by nature as its possession has preceded it. For many years after the colonization of the United States, few or none of the insects which attack wheat in its different stages of growth, were known in America. During the Revolutionary war, the Hes-

---

and they become destructive to the forest because they are driven to the living tree for nutriment and cover. The forest of Fontainebleau is almost wholly without birds, and their absence is ascribed by some writers to the want of water, which, in the thirsty sands of that wood, does not gather into running brooks; but the want of undergrowth is perhaps an equally good reason for their scarcity.

On the other hand, the thinning out of the forest and the removal of underwood and decayed timber, by which it is brought more nearly to the condition of an artificial wood, is often destructive to insect tribes which, though not injurious to trees, are noxious to man. Thus the troublesome woodtick, formerly very abundant in the North Eastern, as it unhappily still is in native forests in the Southern and Western States, has become nearly or quite extinct in the former region since the woods have been reduced in extent and laid more open to the sun and air.—ASA FITCH, in *Report of New York Agricultural Society* for 1870, pp. 363, 364.

sian fly, *Cecidomyia destructrix*, made its appearance, and it was so called because it was first observed in the year when the Hessian troops were brought over, and was popularly supposed to have been accidentally imported by those unwelcome strangers. Other destroyers of cereal grains have since found their way across the Atlantic, and a noxious European aphis has first attacked the American wheatfields within the last fifteen years. Unhappily, in these cases of migration, the natural corrective of excessive multiplication, the parasitic or voracious enemy of the noxious insect, does not always accompany the wanderings of its prey, and the bane long precedes the antidote. Hence, in the United States, the ravages of imported insects injurious to cultivated crops, not being checked by the counteracting influences which nature had provided to limit their devastations in the Old World, are more destructive than in Europe. It is not known that the wheat midge is preyed upon in America by any other insect, and in seasons favorable to it, it multiplies to a degree which would prove almost fatal to the entire harvest, were it not that, in the great territorial extent of the United States, there is room for such differences of soil and climate as, in a given year, to present in one State all the conditions favorable to the increase of a particular insect, while in another, the natural influences are hostile to it. The only apparent remedy for this evil is, to balance the disproportionate development of noxious foreign species by bringing from their native country the tribes which prey upon them. This, it seems, has been attempted. The United States Census Report for 1860, p. 82, states that the New York Agricultural Society "has introduced into this country from abroad certain parasites which Providence has created to counteract the destructive powers of some of these depredators." *

This is, however, not the only purpose for which man has designedly introduced foreign forms of insect life. The eggs of the silkworm are known to have been brought from the farther East to Europe in the sixth century, and new silk-spinners which feed on the castor-oil bean and the ailanthus, have recently been reared in France and in South America with promising success.* The cochineal, long regularly bred in aboriginal America, has been transplanted to Spain, and both the kermes insect and the cantharides have been transferred to other climates than their own. The honey-bee must be ranked next to the silkworm in economical importance. This useful creature was carried to the United States by European colonists, in the latter part of the seventeenth century; it did not cross the Mississippi till the close of the eighteenth, and it is only in 1853 that it was transported to California, where it was previously unknown. The Italian bee, which seldom stings, has lately been introduced into the United States.†

---

* On parasitic and entomophagous insects, see a paper by Rondani referred to p. 119 *ante*.

The insects and worms intentionally transplanted by man bear but a small proportion to those accidentally introduced by him. Plants and animals often carry their parasites with them, and the traffic of commercial countries, which exchange their products with every zone and every stage of social existence, cannot fail to transfer in both directions the minute organisms that are, in one way or another, associated with almost every object important to the material interests of man.*

---

* The silkworm which feeds on the ailanthus has naturalized itself in the United States, but the promises of its utility have not been realized.

† Bee husbandry, now very general in Switzerland and other Alpine regions, was formerly an important branch of industry in Italy. It has lately been revived and is now extensively prosecuted in that country. It is interesting to observe that many of the methods recently introduced into this art in England and the United States, such for example as the removable honey-boxes, are reinventions of Italian systems at least three hundred years old. See GALLO, *Le venti Giornate dell' Agricultura*, cap. xv.

The temporary decline of this industry in Italy was doubtless in a great measure due to the use of sugar which had taken the place of honey, but perhaps also in part to the decrease of the wild vegetation from which the bee draws more or less of his nutriment.

A new wax-producing insect, a species of coccus, very abundant in China, where its annual produce is said to amount to the value of ten millions of francs, has recently attracted notice in France. The wax is white, resembling spermaceti, and is said to be superior to that of the bee.

The tenacity of life possessed by many insects, their prodigious fecundity, the length of time they often remain in the different phases of their existence,† the security of the retreats into which their small dimensions enable them to retire, are all circumstances very favorable not only to the perpetuity of their species, but to their transportation to distant climates and their multiplication in their new homes. The teredo, so destructive to shipping, has been carried by the vessels whose wooden walls it mines to almost every part of the globe. The termite, or white ant, is said to have been brought to Rochefort by the commerce of that port a hundred years ago.‡ This creature is more injurious to wooden structures and implements than any other known insect. It eats out almost the entire substance of the wood, leaving only thin partitions between the galleries it excavates in it; but as it never gnaws through the surface to the air, a stick of timber may be almost wholly consumed without showing any external sign of the damage it has sustained. The termite is found also in other parts of France, and particularly at Rochelle, where, thus far, its ravages are confined to a single quarter of the city. A borer, of similar habits, is not uncommon in Italy, and you may see in that country handsome chairs and other furniture which have been reduced by this insect to a framework of powder of post, covered, and apparently held together, by nothing but the varnish.

---

* A few years ago, a laborer, employed at a North American port in discharging a cargo of hides from the opposite extremity of the continent, was fatally poisoned by the bite or the sting of an unknown insect, which ran out from a hide he was handling.

The *Phylloxera vastatrix*, the most destructive pest which has ever attacked European vineyards—for its ravages are fatal not merely to the fruit, but to the vine itself—is said by many entomologists to be of American origin, but I have seen no account of the mode of its introduction.

† In many insects, some of the stages of life regularly continue for several years, and they may, under peculiar circumstances, be almost indefinitely prolonged. Dr. Dwight mentions the following remarkable case of this sort: "I saw here an insect, about an inch in length, of a brown color tinged with orange, with two antennæ, not unlike a rosebug. This insect came out of a tea-table made of the boards of an apple-tree." Dr. Dwight found the "cavity whence the insect had emerged into the light," to be "about two inches in length. Between the hole, and the outside of the leaf of the table, there were forty grains of the wood." It was supposed that the sawyer and the cabinet-maker must have removed at least thirteen grains more, and the table had been in the possession of its proprietor for twenty years.

‡ It does not appear to be quite settled whether the termites of France are indigenous or imported. See QUATREFAGES, *Souvenirs d'un Naturaliste*, ii., pp. 400, 542, 543.

The white ant has lately appeared at St. Helena and is in a high degree destructive, no wood but teak, and even that not always, resisting it.—*Nature* for March 2d, 1871, p. 362.

Destruction of Insects.

It is well known to naturalists, but less familiarly to common observers, that the aquatic larvæ of some insects which in other stages of their existence inhabit the land, constitute, at certain seasons, a large part of the food of fresh-water fish, while other larvæ, in their turn, prey upon the spawn and even the young of their persecutors.* The larvæ of the mosquito and the gnat are the favorite food of the trout in the wooded regions where those insects abound.† Earlier in the year the trout feeds on the larvæ of the May fly, which is itself very destructive to the spawn of the salmon, and hence, by a sort of house-that-Jack-built, the destruction of the mosquito, that feeds the trout that preys on the May fly that destroys the eggs that hatch the salmon that pampers the epicure, may occasion a scarcity of this latter fish in waters where he would otherwise be abundant. Thus all nature is linked together by invisible bonds, and every organic creature, however low, however feeble, however dependent, is necessary to the well-being of some other among the myriad forms of life with which the Creator has peopled the earth.

---

* I have seen the larva of the dragon-fly in an aquarium bite off the head of a young fish as long as itself.

† Insects and fish—which prey upon and feed each other—are the only forms of animal life that are numerous in the native woods, and their range is, of course, limited by the extent of the waters. The great abundance of the trout, and of other more or less allied genera in the lakes of Lapland, seems to be due to the supply of food provided for them by the swarms of insects which in the larva state inhabit the waters, or, in other stages of their life, are accidentally swept into them. All travellers in the north of Europe speak of the gnat and the mosquito as very serious drawbacks upon the enjoyments of the summer tourist, who visits the head of the Gulf of Bothnia to see the midnight sun, and the brothers Læstadius regard them as one of the great plagues of sub-arctic life. "The persecutions of these insects," says Lars Levi Læstadius [*Culex pipiens*, *Culex reptans*, and *Culex pulicaris*], "leave not a moment's peace, by day or night, to any living creature. Not only man, but cattle, and even birds and wild beasts, suffer intolerably from their bite." He adds in a note, "I will not affirm that they have ever devoured a living man,

I have said that man has promoted the increase of the insect and the worm, by destroying the bird and the fish which feed upon them. Many insects, in the four different stages of their growth, inhabit in succession the earth, the water, and the air. In each of these elements they have their special enemies, and, deep and dark as are the minute recesses in which they hide themselves, they are pursued to the remotest, obscurest corners by the executioners that nature has appointed to punish their delinquencies, and furnished with cunning contrivances for ferreting out the offenders and dragging them into the light of day. One tribe of birds, the woodpeckers, seems to depend for subsistence almost wholly on those insects which breed in dead or dying trees, and it is, perhaps, needless to say that the injury these birds do the forest is imaginary. They do not cut holes in the trunk of the tree to prepare a lodgment for a future colony of boring larvæ, but to extract the worm which has already begun his mining labors. Hence these birds are not found where the forester removes trees as fast as they become fit habitations for such insects. In clearing new lands in the

---

but many young cattle, such as lambs and calves, have been worried out of their lives by them. All the people of Lapland declare that young birds are killed by them, and this is not improbable, for birds are scarce after seasons when the midge, the gnat, and the mosquito are numerous."—*Om Uppodlingar i Lappmarken*, p. 50.

Petrus Læstadius makes similar statements in his *Journal för första året*, p. 285.

United States, dead trees, especially of the spike-leaved kinds, too much decayed to serve for timber, and which, in that state, are worth little for fuel, are often allowed to stand until they fall of themselves. Such *stubs*, as they are popularly called, are filled with borers, and often deeply cut by the woodpeckers, whose strong bills enable them to penetrate to the very heart of the tree and drag out the lurking larvæ. After a few years, the stubs fall, or, as wood becomes valuable, are cut and carried off for firewood, and, at the same time, the farmer selects for felling, in the forest he has reserved as a permanent source of supply of fuel and timber, the decaying trees which, like the dead stems in the fields, serve as a home for both the worm and his pursuer. We thus gradually extirpate this tribe of insects, and, with them, the species of birds which subsist principally upon them. Thus the fine, large, red-headed woodpecker, *Picus erythrocephalus*, formerly very common in New England, has almost entirely disappeared from those States, since the dead trees are gone, and the apples, his favorite vegetable food, are less abundant.

There are even large quadrupeds which feed almost exclusively upon insects. The ant-bear is strong enough to pull down the clay houses built by the species of termites that constitute his ordinary diet, and the curious ai-ai, a climbing quadruped of Madagascar, is provided with a very slender, hook-nailed finger, long enough to reach far into a hole in the trunk of a tree, and extract the worm which bored it.*

Minute Organisms.

Besides the larger inhabitants of the land and of the sea, the quadrupeds, the reptiles, the birds, the amphibia, the crustacea, the fish, the insects, and the worms, there are other countless forms of vital being. Earth, water, the ducts and fluids of vegetable and of animal life, the very air we breathe, are peopled by minute organisms which perform most important functions in both the living and the inanimate kingdoms of nature. Of the offices assigned to these creatures, the most familiar to common observation is the extraction of lime, and, more rarely, of silex, from the waters inhabited by them, and the deposit of these minerals in a solid form, either as the material of their habitations or as the exuviæ of their bodies. The microscope and other means of scientific observation assure us that the chalk-beds of England and of France, the coral reefs of marine waters in warm climates, vast calcareous and silicious deposits in the sea and in many fresh-water ponds, the common polishing earths and slates, and many species of apparently dense and solid rock, are the work of the humble organisms of which I speak, often, indeed, of animalculæ so small as to become visible only by the aid of lenses magnifying thousands of times the linear measures. It is popularly supposed that animalculæ, or what are commonly embraced under the vague name of infusoria, inhabit the water alone, but naturalists have long known that the atmospheric dust transported by every wind and deposited by every calm is full of microscopic life or of its relics. The soil on which the city of Berlin stands, contains, at the depth of ten or fifteen feet below the surface, living elaborators of silex;* and a microscopic examination of a handful of earth connected with the material evidences of guilt has enabled the naturalist to point out the very spot where a crime was committed. It has been computed that one-sixth part of the solid matter let fall by great rivers at their outlets consists of still recognizable infusory shells and shields, and, as the friction of rolling water must reduce many of these fragile structures to a state of comminution which even the microscope cannot resolve into distinct particles and identify as relics of animal or of vegetable life, we must conclude that a considerably larger proportion of river deposits is really the product of animalcules.†

---

* On the destruction of insects by reptiles, see page 125 *ante*.

---

* WITTWER, *Physikalische Geographie*, p. 142.

† To vary the phrase, I make occasional use of *animalcule*, which, as a popular designation, embraces all microscopic organisms. The name is founded

It is evident that the chemical, and in many cases the mechanical, character of a great number of the objects important in the material economy of human life, must be affected by the presence of so large an organic element in their substance, and it is equally obvious that all agricultural and all industrial operations tend to disturb the natural arrangements of this element, to increase or to diminish the special adaptation of every medium in which it lives to the particular orders of being inhabited by it. The conversion of woodland into pasturage, of pasture into plough land, of swamp or of shallow sea into dry ground, the rotations of cultivated crops, must prove fatal to millions of living things upon every rood of surface thus deranged by man, and must, at the same time, more or less fully compensate this destruction of life by promoting the growth and multiplication of other tribes equally minute in dimensions.

I do not know that man has yet endeavored to avail himself, by artificial contrivances, of the agency of these wonderful architects and manufacturers. We are hardly well enough acquainted with their natural economy to devise means to turn their industry to profitable account, and they are in very many cases too slow in producing visible results for an age so impatient as ours. The over-civilization of the nineteenth century cannot wait for wealth to be amassed by infinitesimal gains, and we are in haste to *speculate* upon the powers of nature, as we do upon objects of bargain and sale in our trafficking one with another. But there are still some cases where the little we know of a life, whose workings are invisible to the naked eye, suggests the possibility of advantageously directing the efforts of

---

on the now exploded supposition that all of them are animated, which was the general belief of naturalists when attention was first drawn to them. It was soon discovered that many of them were unquestionably vegetable, and there are numerous genera the true classification of which is matter of dispute among the ablest observers. There are cases in which objects formerly taken for living animalcules turn out to be products of the decomposition of matter once animated, and it is admitted that neither spontaneous motion nor even apparent irritability are sure signs of animal life.

troops of artisans that we cannot see. Upon coasts occupied by the corallines, the reef-building animalcule does not work near the mouth of rivers. Hence the change of the outlet of a stream, often a very easy matter, may promote the construction of a barrier to coast navigation at one point, and check the formation of a reef at another, by diverting a current of fresh water from the former and pouring it into the sea at the latter. Cases may probably be found, in tropical seas, where rivers have prevented the working of the coral animalcules in straits separating islands from each other or from the mainland. The diversion of such streams might remove this obstacle, and reefs consequently be formed which should convert an archipelago into a single large island, and finally join that to the neighboring continent.

Quatrefages proposed to destroy the teredo in harbors by impregnating the water with a mineral solution fatal to them. Perhaps the labors of the coralline animals might be arrested over a considerable extent of sea-coast by similar means. The reef-builders are leisurely architects, but the precious coral is formed so rapidly that the beds may be refished advantageously as often as once in ten years.* It does not seem impossible that branches of this coral might be attached to the keel of a ship and transplanted to the American coast, where the Gulf stream would furnish a suitable temperature beyond the climatic limits that otherwise confine its growth; and thus a new source of profit might perhaps be added to the scanty returns of the hardy fisherman.

In certain geological formations, the diatomaceæ deposit, at the bottom of fresh-water ponds, beds of silicious shields, valuable as a material for a species of very light firebrick, in the manufacture of water-glass and of hydraulic cement, and ultimately, doubtless, in many yet undiscovered industrial processes. An attentive study of the conditions favorable to the propagation of the diatomaceæ might perhaps help us to profit directly by the productivity of this organism, and, at the same time, disclose secrets of nature capable of being turned to valuable account in dealing with silicious rocks, and the metal which is the base of them.

---

* The smallest twig of the precious coral thrown back into the sea attaches itself to the bottom or a rock, and grows as well as on its native stem.

See an interesting report on the coral fishery, by Sant' Agabio, Italian Consul-General at Algiers, in the *Bollettino Consolare*, published by the Department of Foreign Affairs, 1862, pp. 139, 151, and in the *Annali di Agricoltura Industria e Commercio*, No. ii., pp. 360, 373.

Our acquaintance with the obscure and infinitesimal life of which I have now been treating is very recent, and still very imperfect. We know that it is of vast importance in geology, but we are so ambitious to grasp the great, so little accustomed to occupy ourselves with the minute, that we are not yet prepared to enter seriously upon the question how far we can control and utilize the operations, not of unembodied physical forces merely, but of beings, in popular apprehension, almost as immaterial as they.

Disturbance of Natural Balances.

It is highly probable that the reef-builders and other yet unstudied minute forms of vital existence have other functions in the economy of nature besides aiding in the architecture of the globe, and stand in important relations not only to man but to the plants and the larger sentient creatures over which he has dominion. The diminution or multiplication of these unseen friends or foes may be attended with the gravest consequences to all his material interests, and he is dealing with dangerous weapons whenever he interferes with arrangements pre-established by a power higher than his own. The equation of animal and vegetable life is too complicated a problem for human intelligence to solve, and we can never know how wide a circle of disturbance we produce in the harmonies of nature when we throw the smallest pebble into the ocean of organic being.

This much, however, the facts I have hitherto presented authorize us to conclude: as often as we destroy the balance by deranging the original proportions between different orders of spontaneous life, the law of self-preservation requires us to restore the equilibrium, by either directly returning the weight abstracted from one scale, or removing a corresponding quantity from the other. In other words, destruction must be either repaired by reproduction, or compensated by new destruction in an opposite quarter.

The parlor aquarium has taught even those to whom it is but an amusing toy, that the balance of animal and vegetable life must be preserved, and that the excess of either is fatal to the other, in the artificial tank as well as in natural waters. A few years ago, the water of the Cochituate aqueduct at Boston became so offensive in smell and taste as to be quite unfit for use. Scientific investigation found the cause in the too scrupulous care with which aquatic vegetation had been excluded from the reservoir, and the consequent death and decay of the animalculæ, which could not be shut out, nor live in the water without the vegetable element.*

Animalcular Life.

Nature has no unit of magnitude by which she measures her works. Man takes his standards of dimension from himself. The hair's breadth was his minimum until the microscope told him that there are animated creatures to which one of the hairs of his head is a larger cylinder than is the trunk of the giant California *sequoia* to him. He borrows his inch from the breadth of his thumb, his palm and span from the width of his hand and the spread of his fingers, his foot from the length of the organ so named; his cubit is the distance from the tip of his middle finger to his elbow, and his fathom is the space he can measure with his outstretched arms.[*] To a being who instinctively finds the standard of all magnitudes in his own material frame, all objects exceeding his own dimensions are absolutely great, all falling short of them absolutely small. Hence we habitually regard the whale and the elephant as essentially large and therefore important creatures, the animalcule as an essentially small and therefore unimportant organism. But no geological formation owes its origin to the labors or the remains of the huge mammal, while the animalcule composes, or has furnished, the substance of strata thousands of feet in thickness, and extending, in unbroken beds, over many degrees of terrestrial surface. If man is destined to inhabit the earth much longer, and to advance in natural knowledge with the rapidity which has marked his progress in physical science for the last two or three centuries, he will learn to put a wiser estimate on the works of creation, and will derive not only great instruction from studying the ways of nature in her obscurest, humblest walks, but great material advantage from stimulating her productive energies in provinces of her empire hitherto regarded as forever inaccessible, utterly barren.*

---

* It is remarkable that Palissy, to whose great merits as an acute observer I am happy to have frequent occasion to bear testimony, had noticed that vegetation was necessary to maintain the purity of water in artificial reservoirs, though he mistook the rationale of its influence, which he ascribed to the elemental "salt" supposed by him to play an important part in all the operations of nature. In his treatise upon Waters and Fountains, p. 174, of the reprint of 1844, he says: "And in special, thou shalt note one point, the which is understood of few: that is to say, that the leaves of the trees which fall upon the parterre, and the herbs growing beneath, and singularly the fruits, if any there be upon the trees, being decayed, the waters of the parterre shall draw unto them the salt of the said fruits, leaves, and herbs, the which shall greatly better the water of thy fountains, and hinder the putrefaction thereof."

---

[*] The French metrical system seems destined to be adopted throughout the civilized world. It is indeed recommended by great advantages, but it is very doubtful whether they are not more than counterbalanced by the selection of too large a unit of measure, and by the inherent intractability of all decimal systems with reference to fractional divisions. The experience of the whole world has established the superior convenience of a smaller unit, such as the braccio, the cubit, the foot, and the palm or span, and in practical life every man finds that he has much more frequent occasion to use a fraction than a multiple of the metre. Of course, he must constantly employ numbers expressive of several centimetres or millimetres instead of the name of a single smaller unit than the metre. Besides, the metre is not divisible into twelfths, eighths, sixths, or thirds, or the multiples of any of these proportions, two of which at least—the eighth and the third—are of as frequent use as any other fractions. The adoption of a fourth of the earth's circumference as a base for the new measures was itself a departure from the decimal system. Had the Commissioners taken the entire circumference as a base, and divided it into 100,000,000 instead of 10,000,000 parts, we should have had a unit of about sixteen inches, which, as a compromise between the foot and the cubit, would have been much better adapted to universal use than so large a unit as the metre.

---

* The fermentation of liquids, and in many cases the decomposition of semi-solids, formerly supposed to be owing purely to chemical action, are now ascribed by many chemists to vital processes of living minute organisms, both vegetable and animal, and consequently to physiological as well as to chemical forces. Even alcohol is stated to be an animal product. The whole subject of animalcular, or rather minute organic, life, has assumed a new and startling importance from the recent researches of naturalists and physiologists, in the agency of such life, vegetable or animal, in exciting and communicating contagious diseases, and it is extremely probable that what are vaguely called *germs*, to whichever of the organic kingdoms they may be assigned, creatures inhabiting various media, and capable of propagating their kind and rapidly multiplying, are the true seeds of infection and death in the maladies now called zymotic, as well perhaps as in many others.

The literature of this subject is now very voluminous. For observations with high microscopic power on this subject, see BEALE, *Disease Germs, their supposed Nature*, and *Disease Germs, their real Nature*, both published in London in 1870.

The increased frequency of typhoidal, zymotic, and malarious diseases in some parts of the United States, and the now common occurrence of some of them in districts where they were unknown forty years ago, are startling facts, and it is a very interesting question how far man's acts or neglects may have occasioned the change. See *Third Annual Report of Massachusetts State Board of Health* for 1872. The causes and remedies of the insalubrity of Rome and its environs have been for some time the object of careful investigation, and many valuable reports have been published on the subject. Among the most recent of these are: *Relazione sulle condizioni agrarie ed igieniche della Campagna di Roma, per* RAFFAELE PARETO; *Cenni Storici sulla questione dell' Agro Romano di* G. GUERZONI; *Cenni sulle condizioni Fisico-economiche di Roma per* F. GIORDANO; and a very important paper in the journal *Lo Sperimentale* for 1870, by Dr. D. PANTALEONI.

There are climates, parts of California, for instance, where the flesh of dead animals, freely exposed, shows no tendency to putrefaction but dries up and may be almost indefinitely preserved in this condition. Is this owing to the absence of destructive animalcular life in such localities, and has man any agency in the introduction and naturalization of these organisms in regions previously not infested by them?

CHAPTER III.

THE WOODS.

The habitable earth originally wooded—General meteorological influence of the forest—Electrical action of trees—Chemical influence of woods—Trees as protection against malaria—Trees as shelter to ground to the leeward—Influence of the forest as inorganic on temperature—Thermometrical action of trees as organic—Total influence of the forest on temperature—Influence of forests as inorganic on humidity of air and earth—Influence as organic—Balance of conflicting influences—Influence of woods on precipitation—Total climatic action of the forest—Influence of the forest on humidity of soil—The forest in winter—Summer rain, importance of—Influence of the forest on the flow of springs—Influence of the forest on inundations and torrents—Destructive action of torrents—Floods of the Ardèche—Excavation by torrents—Extinction of torrents—Crushing force of torrents—Transporting power of water—The Po and its deposits—Mountain slides—Forest as protection against avalanches—Minor uses of the forest—Small forest plants and vitality of seeds—Locusts do not breed in forests—General functions of forest—General consequences of destruction of—Due proportion of woodland—Proportion of woodland in European countries—Forests of Great Britain—Forests of France—Forests of Italy—Forests of Germany—Forests of United States—American forest trees—European and American forest trees compared—The forest does not furnish food for man—First removal of the forest—Principal causes of destruction of forest—Destruction and protection of forests by governments—Royal forests and game-laws—Effects of the French revolution—Increased demand for lumber—Effects of burning forest—Floating of timber—Restoration of the forest—Economy of the forest—Forest legislation—Plantation of forests in America—Financial results of forest plantations—Instability of American life.

The Habitable Earth originally Wooded.

THERE is good reason to believe that the surface of the habitable earth, in all the climates and regions which have been the abodes of dense and civilized populations, was, with few exceptions, already covered with a forest growth when it first became the home of man. This we infer from the extensive vegetable remains—trunks, branches, roots, fruits, seeds, and leaves of trees—so often found in conjunction with works of primitive art, in the boggy soil of districts where no forests appear to have existed within the eras through which written annals reach; from ancient historical records, which prove that large provinces, where the earth has long been wholly bare of trees, were clothed with vast and almost unbroken woods when first made known to Greek and Roman civilization; * and from the state of much of North and of South America, as well as of many islands, when they were discovered and colonized by the European race.†

These evidences are strengthened by observation of the natural economy of our own time; for, whenever a tract of country, once inhabited and cultivated by man, is abandoned by him and by domestic animals, and surrendered to the undisturbed influences of spontaneous nature, its soil sooner or later clothes itself with herbaceous and arborescent plants, and, at no long interval, with a dense forest growth. Indeed, upon surfaces of a certain stability and not absolutely precipitous inclination, the special conditions required for the spontaneous propagation of trees may all be negatively expressed and reduced to these three: exemption from defect or excess of

---

* The recorded evidence in support of the proposition in the text has been collected by L. F. Alfred Maury, in his *Histoire des grandes Forêts de la Gaule et de l'ancienne France*, and by Becquerel, in his important work, *Des climats et de l'Influence qu'exercent les Sols boisés et non boisés*, livre ii., chap. i. to iv.

We may rank among historical evidences on this point, if not technically among historical records, old geographical names and terminations etymologically indicating forest or grove, which are so common in many parts of the Eastern Continent now entirely stripped of woods—such as, in Southern Europe, Breuil, Broglio, Brolio, Brolo; in Northern, Brühl, and the endings -dean, -den, -don, -ham, -holt, -horst, -hurst, -lund, -shaw, -shot, -skog, -skov, -wald, -weald, -wold, -wood.

† The island of Madeira, whose noble forests were devastated by fire not long after its colonization by European settlers, takes its name from the Portuguese word for wood.

moisture, from perpetual frost, and from the depredations of man and browsing quadrupeds. Where these requisites are secured, the hardest rock is as certain to be overgrown with wood as the most fertile plain, though, for obvious reasons, the process is slower in the former than in the latter case. Lichens and mosses first prepare the way for a more highly organized vegetation. They retain the moisture of rains and dews, and bring it to act, in combination with the gases evolved by their organic processes, in decomposing the surface of the rocks they cover; they arrest and confine the dust which the wind scatters over them, and their final decay adds new material to the soil already half formed beneath and upon them. A very thin stratum of mould is sufficient for the germination of seeds of the hardy evergreens and birches, the roots of which are often found in immediate contact with the rock, supplying their trees with nourishment from a soil deepened and enriched by the decomposition of their own foliage, or sending out long rootlets into the surrounding earth in search of juices to feed them.

The eruptive matter of volcanoes, forbidding as is its aspect, does not refuse nutriment to the woods. The refractory lava of Etna, it is true, remains long barren, and that of the great eruption of 1669 is still almost wholly devoid of vegetation.* But the cactus is making inroads even here, while the volcanic sand and molten rock thrown out by Vesuvius soon become productive. Before the great eruption of 1631 even the interior of the crater was covered with vegetation. George Sandys, who visited Vesuvius in 1611, after it had reposed for several centuries, found the throat of the volcano at the bottom of the crater "almost choked with broken rocks and *trees* that are falne therein." "Next to this," he continues, "the matter thrown up is ruddy, light, and soft: more removed, blacke and ponderous: the uttermost brow, that declineth like the seates in a theater, flourishing with trees and excellent pasturage. The midst of the hill is shaded with chestnut trees, and others bearing sundry fruits." *

---

* Even the volcanic dust of Etna remains very long unproductive. Near Nicolosi is a great extent of coarse black sand, thrown out in 1669, which, for almost two centuries, lay entirely bare, and can be made to grow plants only by artificial mixtures and much labor.

The increase in the price of wines, in consequence of the diminution of the product from the grape disease, however, has brought even these ashes under cultivation. "I found," says Waltershausen, referring to the years 1861–62, "plains of volcanic sand and half-subdued lava streams, which twenty years ago lay utterly waste, now covered with fine vineyards. The ashfield of ten square miles above Nicolosi, created by the eruption of 1669, which was entirely barren in 1835, is now planted with vines almost to the summits of Monte Rosso, at a height of three thousand feet."—*Ueber den Sicilianischen Ackerbau*, p. 19.

I am convinced that forests would soon cover many parts of the Arabian and African deserts, if man and domestic animals, especially the goat and the camel, were banished from them. The hard palate and tongue and strong teeth and jaws of this latter quadruped enable him to break off and masticate tough and thorny branches as large as the finger. He is particularly fond of the smaller twigs, leaves, and seed-pods of the *sont* and other acacias, which, like the American Robinia, thrive well on dry and sandy soils, and he spares no tree the branches of which are within his reach, except, if I remember right, the tamarisk that produces manna. Young trees sprout plentifully around the springs and along the winter water-courses of the desert, and these are just the halting stations of the caravans and their routes of travel. In the shade of these trees, annual grasses and perennial shrubs shoot up, but are mown down by the hungry cattle of the Bedouin, as fast as they grow. A few years of undisturbed vegetation would suffice to cover such points with groves, and these would gradnally extend themselves over soils where now scarcely any green thing but the bitter colocynth and the poisonous foxglove is ever seen.

---

* *A Relation of a Journey Begun An. Dom.* 1610, lib. 4, p. 260, edition of 1615. The testimony of Sandys on this point is confirmed by that of Pighio, Braccini, Magliocco, Salimbeni, and Nicola di Rubeo, all cited by Roth, *Der Vesuv.*, p. 9. There is some uncertainty about the date of the last eruption previous to the great one of 1631. Ashes, though not lava, appear to have been thrown out about the year 1500, and some chroniclers have recorded an eruption in the year 1306; but this seems to be an error for 1036, when a great quantity of lava was ejected. In 1139, ashes were thrown out for many days. I take these dates from the work of Roth just cited.

General Meteorological Influence of the Forest.

The physico-geographical influence of forests may be divided into two great classes, each having an important influence on vegetable and on animal life in all their manifestations, as well as on every branch of rural economy and productive industry, and, therefore, on all the material interests of man. The first respects the meteorology of the countries exposed to the action of these influences; the second, their superficial geography, or, in other words, the configuration, consistence, and clothing of their surface.

For reasons assigned in the first chapter, and for others that will appear hereafter, the meteorological or climatic branch of the subject is the most obscure, and the conclusions of physicists respecting it are, in a great degree, inferential only, not founded on experiment or direct observation. They are, as might be expected, somewhat discordant, though one general result is almost universally accepted, and seems indeed too well supported to admit of serious question, and it may be considered as established that forests tend to mitigate, at least within their own precincts, extremes of temperature, humidity, and drought. By what precise agencies the meteorological effects of the forest are produced we cannot say, because elements of totally unknown value enter into its action, and because the relative intensity of better understood causes cannot be measured or compared. I shall not occupy much space in discussing questions which at present admit of no solution, but I propose to notice all the known forces whose concurrent or conflicting energies contribute to the general result, and to point out, in some detail, the value of those influences whose mode of action has been ascertained.

Electrical Influence of Trees.

The properties of trees, singly and in groups, as exciters or conductors of electricity, and their consequent influence upon the electrical state of the atmosphere, do not appear to have been much investigated; and the conditions of the forest itself are so variable and so complicated, that the solution of any general problem respecting its electrical influence would be a matter of extreme difficulty. It is, indeed, impossible to suppose that a dense cloud, a sea of vapor, can pass over miles of surface bristling with good conductors, without undergoing and producing some change of electrical condition. Hypothetical cases may be put in which the character of the change could be deduced from the known laws of electrical action. But in actual nature, the elements are too numerous for us to seize. The true electrical condition of neither cloud nor forest could be known, and it could seldom be predicted whether the vapors would be dissolved as they floated over the wood, or discharged upon it in a deluge of rain. With regard to possible electrical influences of the forest, wider still in their range of action, the uncertainty is even greater. The data which alone could lead to positive, or even probable, conclusions are wanting, and we should, therefore, only embarrass our argument by any attempt to discuss this meteorological element, important as it may be, in its relations of cause and effect to more familiar and better understood meteoric phenomena. It may, however, be observed that hail-storms—which were once generally supposed, and are still held by many, to be produced by a specific electrical action, and which, at least, appear to be always accompanied by electrical disturbances—are believed, in all countries particularly exposed to that scourge, to have become more frequent and destructive in proportion as the forests have been cleared. Caimi observes: "When the chains of the Alps and the Apennines had not yet been stripped of their magnificent crown of woods, the May hail, which now desolates the fertile plains of Lombardy, was much less frequent; but since the general prostration of the forest, these tempests are laying waste even the mountain-soils whose older inhabitants scarcely knew this plague.[*] The *paragrandini*,[†] which the learned curate of Rivolta advised to erect, with sheaves of straw set up vertically, over a great extent of cultivated country, are but a Liliputian image of the vast paragrandini, pines, larches, and firs, which nature had planted by millions on the crests and ridges of the Alps and the Apennines."[‡] "Electrical action being diminished," says Meguscher, "and the rapid congelation of vapors by the abstraction of heat being impeded by the influence of the woods, it is rare that hail or waterspouts are produced within the precincts of a large forest when it is assailed by the tempest."[§] Arthur Young was told that since the forests which covered the mountains between the Riviera and the county of Montferrat had disappeared, hail had become more destructive in the district of Acqui,[‖] and a similar increase in the frequency and violence of hail-storms in the neighborhood of Saluzzo and Mondovì, the lower part of the Valtelline, and the territory of Verona and Vicenza, is probably to be ascribed to a similar cause.*

---

[*] There are, in Northern Italy and in Switzerland, joint-stock companies which insure against damage by hail, as well as by fire and lightning. Between the years 1854 and 1861, a single one of these companies, La Riunione Adriatica, paid, for damage by hail in Piedmont, Venetian Lombardy, and the Duchy of Parma, above 6,500,000 francs, or nearly $200,000 per year.

[†] The *paragrandine*, or, as it is called in French, the *paragrêle*, is a species of conductor by which it has been hoped to protect the harvests in countries particularly exposed to damage by hail. It was at first proposed to employ for this purpose poles supporting sheaves of straw connected with the ground by the same material; but the experiment was afterwards tried in Lombardy on a large scale, with more perfect electrical conductors, consisting of poles secured to the top of tall trees and provided with a pointed wire entering the ground and reaching above the top of the pole. It was at first thought that this apparatus, erected at numerous points over an extent of several miles, was of some service as a protection against hail, but this opinion was soon disputed, and does not appear to be supported by well-ascertained facts. The question of a repetition of the experiment over a wide area has been again agitated within a very few years in Lombardy; but the doubts expressed by very able physicists as to its efficacy, and as to the point whether hail is an electrical phenomenon, have discouraged its advocates from attempting it.

[‡] *Cenni sulla Importanza e Coltura dei Boschi*, p. 6.

[§] *Memoria sui Boschi*, etc., p. 44.

[‖] *Travels in Italy*, chap. iii.

Chemical Influence of the Forest.

We know that the air in a close apartment is appreciably affected through the inspiration and expiration of gases by plants growing in it. The same operations are performed on a gigantic scale by the forest, and it has even been supposed that the absorption of carbon, by the rank vegetation of earlier geological periods, occasioned a permanent change in the constitution of the terrestrial atmosphere.† To the effects thus produced are to be added those of the ultimate gaseous decomposition of the vast vegetable mass annually shed by trees, and of their trunks and branches when they fall a prey to time. But the quantity of gases thus abstracted from and restored to the atmosphere is inconsiderable—infinitesimal, one might almost say—in comparison with the ocean of air from which they are drawn and to which they return; and though the exhalations from bogs, and other low grounds covered with decaying vegetable matter, are highly deleterious to human health, yet, in general, the air of the forest is hardly chemically distinguishable from that of the sand plains, and we can as little trace the influence of the woods in the analysis of the atmosphere, as we can prove that the mineral ingredients of land-springs sensibly affect the chemistry of the sea. I may, then, properly dismiss the chemical, as I have done the electrical, influences of the forest, and treat them both alike, if not as unimportant agencies, at least as quantities of unknown value in our meteorological equation.* Our inquiries upon this branch of the subject will accordingly be limited to the thermometrical and hygrometrical influences of the woods. There is, however, a special protective function of the forest, perhaps, in part, of a chemical nature, which may be noticed here.

---

* *Le Alpi che cingono l'Italia*, i., p. 377. See "On the Influence of the Forest in Preventing Hail-storms," a paper by Becquerel, in the *Mémoires de l'Académie des Sciences*, vol. xxxv. The conclusion of this eminent physicist is, that woods do exercise, both within their own limits and in their vicinity, the influence popularly ascribed to them in this respect, and that the effect is probably produced partly by mechanical and partly by electrical action.

† "Long before the appearance of man, ... they [the forests] had robbed the atmosphere of the enormous quantity of carbonic acid it contained, and thereby transformed it into respirable air. Trees heaped upon trees had already filled up the ponds and marshes, and buried with them in the bowels of the earth—to restore it to us, after thousands of ages, in the form of bituminous coal and of anthracite—the carbon which was destined to become, by this wonderful condensation, a precious store of future wealth."—CLAVÉ, *Études sur l'Économie Forestière*, p. 13.

This opinion of the modification of the atmosphere by vegetation is contested.

Mossman ascribes the great luxuriance and special character of the Australian and New Zealand forests, as well as other peculiarities of the vegetation of the Southern hemisphere, to a supposed larger proportion of carbon in the atmosphere of that hemisphere, though the fact of such excess does not appear to have been established by chemical analysis.—MOSSMAN, *Origin of the Seasons*. Edinburgh, 1869. Chaps. xvi. and xvii.

Trees as a Protection against Malaria.

The influence of forests in preventing the diffusion of miasmatic vapors is not a matter of familiar observation, and perhaps it does not come strictly within the sphere of the present inquiry, but its importance will justify me in devoting some space to the subject. "It has been observed" (I quote from Becquerel) "that humid air, charged with miasmata, is deprived of them in passing through the forest. Rigaud de Lille observed localities in Italy where the interposition of a screen of trees preserved everything beyond it, while the unprotected grounds were subject to fevers."[*] Few European countries present better opportunities for observation on this point than Italy, because in that kingdom the localities exposed to miasmatic exhalations are numerous, and belts of trees, if not forests, are of so frequent occurrence that their efficacy in this respect can be easily tested. The belief that rows of trees afford an important protection against malarious influences is very general among Italians best qualified by intelligence and professional experience to judge upon the subject. The commissioners, appointed to report on the measures to be adopted for the improvement of the Tuscan Maremme, advised the planting of three or four rows of poplars, *Populus alba*, in such directions as to obstruct the currents of air from malarious localities, and thus intercept a great proportion of the pernicious exhalations."[†] Maury believed that a few rows of sunflowers, planted between the Washington Observatory and the marshy banks of the Potomac, had saved the inmates of that establishment from the intermittent fevers to which they had been formerly liable. Maury's experiments have been repeated in Italy. Large plantations of sunflowers have been made upon the alluvial deposits of the Oglio, above its entrance into the Lake of Iseo, near Pisogne, and it is said with favorable results to the health of the neighborhood.[‡] In fact, the generally beneficial effects of a forest wall or other vegetable screen, as a protection against noxious exhalations from marshes or other sources of disease, situated to the windward of them, are very commonly admitted.

---

* Schacht ascribes to the forest a specific, if not a measurable, influence upon the constitution of the atmosphere. "Plants imbibe from the air carbonic acid and other gaseous or volatile products exhaled by animals or developed by the natural phenomena of decomposition. On the other hand, the vegetable pours into the atmosphere oxygen, which is taken up by animals and appropriated by them. The tree, by means of its leaves and its young herbaceous twigs, presents a considerable surface for absorption and evaporation; it abstracts the carbon of carbonic acid, and solidifies it in wood, fecula, and a multitude of other compounds. The result is that a forest withdraws from the air, by its great absorbent surface, much more gas than meadows or cultivated fields, and exhales proportionally a considerably greater quantity of oxygen. The influence of the forests on the chemical composition of the atmosphere is, in a word, of the highest importance."—*Les Arbres*, p. 111.

See on this subject a paper by J. Jamin, in the *Revue des Deux Mondes* for Sept. 15, 1864; and, on the effects of human industry on the atmosphere, an article in *Aus der Natur*, vol. 29, 1864, pp. 443, 449, 465, *et seq.* See also ALFRED MAURY, *Les Forêts de la Gaule*, p. 107.

---

[*] BECQUEREL, *Des Climats*, etc., p. 9.

[†] SALVAGNOLI, *Rapporto sul Bonificamento delle Maremme Toscane*, pp. xli., 124.

[‡] *Il Politecnico, Milano, Aprile e Maggio*, 1863, p. 35.

It is argued that, in these cases, the foliage of trees and of other vegetables exercises a chemical as well as a mechanical effect upon the atmosphere, and some, who allow that forests may intercept the circulation of the miasmatic effluvia of swampy soils, or even render them harmless by decomposing them, contend, nevertheless, that they are themselves active causes of the production of malaria. The subject has been a good deal discussed in Italy, and there is some reason to think that under special circumstances the influence of the forest in this respect may be prejudicial rather than salutary, though this does not appear to be generally the case.[*] It is, at all

---

[*] Salvagnoli, *Memorie sulle Maremme Toscane*, pp. 213, 214. The sanitary action of the forest has been lately matter of much attention in Italy. See *Rendiconti del Congresso Medico del* 1869 *a Firenze*, and especially the important observations of Selmi, *Il Miasma Palustre*, Padua, 1870, pp. 109 *et seq.* This action is held by this able writer to be almost wholly chemical, and he earnestly recommends the plantation of groves, at least of belts of trees, as an effectual protection against the miasmatic influence of marshes. Very interesting observations on this point will be found in Ebermayer, *Die Physikalischen Einwirkungen des Waldes*, Aschaffenburg, 1873, B. I., pp. 237 *et seq.*, where great importance is ascribed to the development of ozone by the chemical action of the forest. The beneficial influence of the ozone of the forest atmosphere on the human system is, however, questioned by some observers. See also the able memoir: *Del Miasma vegetale e delle Malattie Miasmatiche* of Dr. D. Pantaleoni in *Lo Sperimentale*, vol. xxii., 1870.

The necessity of such hygienic improvements as shall render the new capital of Italy a salubrious residence gives great present importance to this question, and it is much to be hoped that the Agro Romano, as well as more distant parts of the Campagna, will soon be dotted with groves and traversed by files of rapidly growing trees. Many forest trees grow with great luxuriance in Italy, and a moderate expense in plantation would in a very few years determine whether any amelioration of the sanitary condition of Rome can be expected from this measure.

It is said by recent writers that in India the villages of the natives and the encampments of European troops, situated in the midst or in the neighborhood of groves and of forests, are exempt from cholera. Similar observations were also made in 1854 in Germany when this terrible disease was raging there. It is hence inferred that forests prevent the spreading of this malady, or rather the development of those unknown influences of which cholera is events, well known that the great swamps of Virginia and the Carolinas, in climates nearly similar to that of Italy, are healthy even to the white man, so long as the forests in and around them remain, but become very insalubrious when the woods are felled.[*]

Trees as Shelter to Ground to the Leeward.

As a mechanical obstruction, trees impede the passage of air-currents over the ground, which, as is well known, is one of the most efficient agents in promoting evaporation and the refrigeration resulting from it.[†] In the forest, the air is almost

---

the result. These influences, if we may believe certain able writers on medical subjects, are telluric rather than meteoric; and they regard it as probable that the uniform moisture of soil in forests may be the immediate cause of the immunity enjoyed by such localities. See an article by Pettenkofer in the *Süd-Deutsche Presse*, August, 1869; and the observations of Ebermayer in the work above quoted, pp. 243 *et seq.*

In Australia and New Zealand, as well as generally in the Southern Hemisphere, the indigenous trees are all evergreens, and even deciduous trees introduced from the other side of the equator become evergreen. In those regions, even in the most swampy localities, malarious diseases are nearly, if not altogether, unknown. Is this most important fact due to the persistence of the foliage?

Mossman, *Origin of Climates*, pp. 374, 393, 410, 425, *et seq.*

[*] Except in the seething marshes of northern tropical and subtropical regions, where vegetable decay is extremely rapid, the uniformity of temperature and of atmospheric humidity renders all forests eminently healthful. See Hohenstein's observations on this subject, *Der Wald*, p. 41; also A. Maury, *Les Forêts de la Gaule*, p. 7.

The flat and marshy district of the Sologne in France was salubrious until its woods were felled. It then became pestilential, but within the last few years its healthfulness has been restored by forest plantations. Jules Clavé in *Revue des Deux Mondes* for 1st March, 1866, p. 209.

There is no question that open squares and parks conduce to the salubrity of cities, and many observers are of opinion that the trees and other vegetables with which such grounds are planted contribute essentially to their beneficial influence. See an article in *Aus der Natur*, xxii., p. 813.

[†] It is perhaps too much to say that the influence of trees upon the wind is strictly limited to the mechanical resistance of their trunks, branches, and foliage. So far as the forest, by dead or by living action, raises or

quiescent, and moves only as local changes of temperature affect the specific gravity of its particles. Hence there is often a dead calm in the woods when a furious blast is raging in the open country at a few yards' distance. The denser the forest —as, for example, where it consists of spike-leaved trees, or is thickly intermixed with them—the more obvious is its effect, and no one can have passed from the field to the wood in cold, windy weather, without having remarked it.*

---

lowers the temperature of the air within it, so far it creates upward or downward currents in the atmosphere above it, and, consequently, a flow of air towards or from itself. These air-streams have a certain, though doubtless a very small, influence on the force and direction of greater atmospheric movements.

* As a familiar illustration of the influence of the forest in checking the movement of winds, I may mention the well-known fact, that the sensible cold is never extreme in thick woods, where the motion of the air is little felt. The lumbermen in Canada and the Northern United States labor in the woods, without inconvenience, when the mercury stands many degrees below the zero of Fahrenheit, while in the open grounds, with only a moderate breeze, the same temperature is almost insupportable. The engineers and firemen of locomotives, employed on railways running through forests of any considerable extent, observe that, in very cold weather, it is much easier to keep up the steam while the engine is passing through the woods than in the open ground. As soon as the train emerges from the shelter of the trees the steam-gauge falls, and the stoker is obliged to throw in a liberal supply of fuel to bring it up again.

Another less frequently noticed fact, due, no doubt, in a great measure to the immobility of the air, is, that sounds are transmitted to incredible distances in the unbroken forest. Many instances of this have fallen under my own observation, and others, yet more striking, have been related to me by credible and competent witnesses familiar with a more primitive condition of the Anglo-American world. An acute observer of natural phenomena, whose childhood and youth were spent in the interior of one of the newer New England States, has often told me that when he established his home in the forest, he always distinctly heard, in still weather, the plash of horses' feet, when they forded a small brook nearly seven-eighths of a mile from his house, though a portion of the wood that intervened consisted of a ridge seventy or eighty feet higher than either the house or the ford.

I have no doubt that, in such cases, the stillness of the air is the most important element in the extraordinary transmissibility of sound; but it must be admitted that the absence of the multiplied and confused noises, The action of the forest, considered merely as a mechanical shelter to grounds lying to the leeward of it, might seem to be an influence of too restricted a character to deserve much notice; but many facts concur to show that it is a most important element in local climate.

---

which accompany human industry in countries thickly peopled by man, contributes to the same result. We become, by habit, almost insensible to the familiar and never-resting voices of civilization in cities and towns; but the indistinguishable drone, which sometimes escapes even the ear of him who listens for it, deadens and often quite obstructs the transmission of sounds which would otherwise be clearly audible. An observer, who wishes to appreciate that hum of civic life which he cannot analyze, will find an excellent opportunity by placing himself on the hill of Capo di Monte at Naples, in the line of prolongation of the street called Spaccanapoli.

It is probably to the stillness of which I have spoken that we are to ascribe the transmission of sound to great distances at sea in calm weather. In June, 1853, I and my family were passengers on board a ship-of-war bound up the Ægean. On the evening of the 27th of that month, as we were discussing, at the tea-table, some observations of Humboldt on this subject, the captain of the ship told us that he had once heard a single gun at sea at the distance of ninety nautical miles. The next morning, though a light breeze had sprung up from the north, the sea was of glassy smoothness when we went on deck. As we came up, an officer told us that he had heard a gun at sunrise, and the conversation of the previous evening suggested the inquiry whether it could have been fired from the combined French and English fleet then lying at Beshika Bay. Upon examination of our position we were found to have been, at sunrise, ninety sea miles from that point. We continued beating up northwards, and between sunrise and twelve o'clock meridian of the 28th, we had made twelve miles northing, reducing our distance from Beshika Bay to seventy-eight sea miles. At noon we heard several guns so distinctly that we were able to count the number. On the 29th we came up with the fleet, and learned from an officer who came on board that a royal salute had been fired at noon on the 28th, in honor of the day as the anniversary of the Queen of England's coronation. The report at sunrise was evidently the morning gun, those at noon the salute.

Such cases are rare, because the sea is seldom still, and the *κυμάτων ἀνήριϑμον γέλασμα* rarely silent, over so great a space as ninety or even seventy-eight nautical miles. I apply the epithet *silent* to *γέλασμα* advisedly. I am convinced that Æschylus meant the audible laugh of the waves, which is indeed of *countless* multiplicity, not the visible smile of the sea, which, belonging to the great expanse as one impersonation, is single, though, like the human smile, made up of the play of many features.

It is evident that the effect of the forest, as a mechanical impediment to the passage of the wind, would extend to a very considerable distance above its own height, and hence protect while standing, or lay open when felled, a much larger surface than might at first thought be supposed. The atmosphere, movable as are its particles, and light and elastic as are its masses, is nevertheless held together as a continuous whole by the gravitation of its atoms and their consequent pressure on each other, if not by attraction between them, and, therefore, an obstruction which mechanically impedes the movement of a given stratum of air will retard the passage of the strata above and below it. To this effect may often be added that of an ascending current from the forest itself, which must always exist when the atmosphere within the wood is warmer than the stratum of air above it, and must be of almost constant occurrence in the case of cold winds, from whatever quarter, because the still air in the forest is slow in taking up the temperature of the moving columns and currents around and above it. Experience, in fact, has shown that mere rows of trees, and even much lower obstructions, are of essential service in defending vegetation against the action of the wind. Hardy proposes planting, in Algeria, belts of trees at the distance of one hundred mètres from each other, as a shelter which experience had proved to be useful in France.* "In the valley of the Rhone," says Becquerel, "a simple hedge, two mètres in height, is a sufficient protection for a distance of twenty-two mètres."† The mechanical shelter acts, no doubt, chiefly as a defence against the mechanical force of the wind, but its uses are by no means limited to this effect. If the current of air which it resists moves horizontally, it would prevent the access of cold or parching blasts to the ground for a great distance; and did the wind even descend at a large angle with the surface, still a considerable extent of ground would be protected by a forest to the windward of it.

---

* BECQUEREL, *Des Climats*, etc., p. 179. † Ibid., p. 116.

Becquerel's views have been amply confirmed by recent extensive experiments on the bleak, stony, and desolate plain of the Crau in the Department of the Bouches-du-Rhone, which had remained a naked waste from the earliest ages of history. Belts of trees prove a secure protection even against the furious and chilly blasts of the Mistral, and in this shelter plantations of fruit-trees and vegetables, fertilized by the waters and the slime of the Durance, which are conducted and distributed over the Crau, thrive with the greatest luxuriance.

SURELL, *Étude sur les Torrents*, 2d edition, 1872, ii., p. 35.

In the report of a committee appointed in 1836 to examine an article of the forest code of France, Arago observes: "If a curtain of forest on the coasts of Normandy and of Brittany were destroyed, these two provinces would become accessible to the winds from the west, to the mild breezes of the sea. Hence a decrease of the cold of winter. If a similar forest were to be cleared on the eastern border of France, the glacial east wind would prevail with greater strength, and the winters would become more severe. Thus the removal of a belt of wood would produce opposite effects in the two regions." *

This opinion receives confirmation from an observation of Dr. Dwight, who remarks, in reference to the woods of New England: "Another effect of removing the forest will be the free passage of the winds, and among them of the southern winds, over the surface. This, I think, has been an increasing fact within my own remembrance. As the cultivation of the country has extended farther to the north, the winds from the south have reached distances more remote from the ocean, and imparted their warmth frequently, and in such degrees as, forty years since, were in the same places very little known. This fact, also, contributes to lengthen the summer and to shorten the winter half of the year." †

It is thought in Italy that the clearing of the Apennines has very materially affected the climate of the valley of the Po. It is asserted in *Le Alpi che cingono l'Italia* that: "In consequence of the felling of the woods on the Apennines, the sirocco prevails greatly on the right bank of the Po, in the

---

* BECQUEREL, *Des Climats*, etc., *Discours Prélim.*, vi.

† *Travels*, i., p. 61.

Parmesan territory, and in a part of Lombardy; it injures the harvests and the vineyards, and sometimes ruins the crops of the season. To the same cause many ascribe the meteorological changes in the precincts of Modena and of Reggio. In the communes of these districts, where formerly straw roofs resisted the force of the winds, tiles are now hardly sufficient; in others, where tiles answered for roofs, large slabs of stone are now ineffectual; and in many neighboring communes the grapes and the grain are swept off by the blasts of the south and south-west winds."

According to the same authority, the pinery of Porto, near Ravenna—which is twenty miles long, and is one of the oldest pine woods in Italy—having been replanted with resinous trees after it was unfortunately cut, has relieved the city from the sirocco to which it had become exposed, and in a great degree restored its ancient climate.[*]

The felling of the woods on the Atlantic coast of Jutland has exposed the soil not only to drifting sands, but to sharp sea-winds, that have exerted a sensible deteriorating effect on the climate of that peninsula, which has no mountains to serve at once as a barrier to the force of the winds, and as a storehouse of moisture received by precipitation or condensed from atmospheric vapors.[†]

---

[*] *Le Alpi che cingono l'Italia*, pp. 370, 371.

[†] BERGSÖE, *Reventlovs Virksomhed*, ii., p. 125.

The following well-attested instance of a local change of climate is probably to be referred to the influence of the forest as a shelter against cold winds. To supply the extraordinary demand for Italian iron occasioned by the exclusion of English iron in the time of Napoleon I., the furnaces of the valleys of Bergamo were stimulated to great activity. "The ordinary production of charcoal not sufficing to feed the furnaces and the forges, the woods were felled, the copses cut before their time, and the whole economy of the forest was deranged. At Piazzatorre there was such a devastation of the woods, and consequently such an increased severity of climate, that maize no longer ripened. An association, formed for the purpose, effected the restoration of the forest, and maize flourishes again in the fields of Piazzatorre."—Report by G. ROSA, in *Il Politecnico*, Dicembre, 1861, p. 614.

Similar ameliorations have been produced by plantations in Belgium. In an interesting series of articles by Baude, entitled, "Les Côtes de la Manche," The local retardation of spring, so much complained of in Italy, France, and Switzerland, and the increased frequency of late frosts at that season, appear to be ascribable to the admission of cold blasts to the surface, by the felling of the forests which formerly both screened it as by a wall, and communicated the warmth of their soil to the air and earth to the leeward. Caimi states that since the cutting down of the woods of the Apennines, the cold winds destroy or stunt the vegetation, and that, in consequence of "the usurpation of winter on the domain of spring," the district of Mugello has lost all its mulberries, except the few which find in the lee of buildings a protection like that once furnished by the forest.[*]

The department of Ardèche, which now contains not a single considerable wood, has experienced within thirty years a climatic disturbance, of which the late frosts, formerly unknown in the country, are one of the most melancholy effects. Similar results have been observed in the plain of Alsace, in consequence of the denudation of several of the crests of the Vosges.[†]

Dussard, as quoted by Ribbe,[‡] maintains that even the

---

in the *Revue des Deux Mondes*, I find this statement: "A spectator, placed on the famous bell-tower of the cathedral of Antwerp, saw, not long since, on the opposite side of the Schelde, only a vast desert plain; now he sees a forest, the limits of which are confounded with the horizon. Let him enter within its shade. The supposed forest is but a system of regular rows of trees, the oldest of which is not forty years of age. These plantations have ameliorated the climate which had doomed to sterility the soil where they are planted. While the tempest is violently agitating their tops, the air a little below is still, and sands far more barren than the plateau of La Hague have been transformed, under their protection, into fertile fields."—*Revue des Deux Mondes*, January, 1859, p. 277.

[*] *Cenni sulla Importanza e Coltura dei Boschi*, p. 31.

[†] CLAVÉ, *Études*, p. 44.

It has been observed in Sweden that the spring, in many districts where the forests have been cleared off, now comes on a fortnight later than in the last century.—ASBJÖRNSEN, *Om Skovene i Norge*, p. 101.

[‡] *La Provence au point de vue des Torrents et des Inondations*, p. 19.

Dussard is doubtless historically inaccurate in making the origin of the mistral so late as the time of Augustus. Diodorus Siculus, who was a contemporary of Julius Cæsar, describes the north-west winds in Gaul as *mistral*, or north-west wind, whose chilling blasts are so fatal to tender vegetation in the spring, "is the child of man, the result of his devastations." "Under the reign of Augustus," continues he, "the forests which protected the Cévennes were felled, or destroyed by fire, in mass. A vast country, before covered with impenetrable woods—powerful obstacles to the movement and even to the formation of hurricanes—was suddenly denuded, swept bare, stripped, and soon after, a scourge hitherto unknown, struck terror over the land from Avignon to the Bouches-du-Rhone, thence to Marseilles, and then extended its ravages, diminished indeed by a long career which had partially exhausted its force, over the whole maritime frontier. The people thought this wind a curse sent of God. They raised altars to it and offered sacrifices to appease its rage." It seems, however, that this plague was less destructive than at present, until the close of the sixteenth century, when further clearings had removed most of the remaining barriers to its course. Up to that time, the north-west wind appears not to have attained to the maximum of specific effect which now characterizes it as a local phenomenon. Extensive districts, from which the rigor of the seasons has now banished valuable crops, were not then exposed to the loss of their harvests by tempests, cold, or drought. The deterioration was rapid in its progress. Under the Consulate, the clearings had exerted so injurious an effect upon the climate, that the cultivation of the olive had retreated several leagues, and since the winters and springs of 1820 and 1836, this branch of rural industry has been abandoned in a great number of localities where it was advantageously pursued before. The orange now flourishes only at a few sheltered points of the coast, and it is threatened even at Hyères, where the clearing of the

---

violent enough to hurl along stones as large as the fist with clouds of sand and gravel, to strip travellers of their arms and clothing, and to throw mounted men from their horses. *Bibliotheca Historica*, lib. v., c. xxvi. Diodorus, it is true, is speaking of the climate of Gaul in general, but his description can hardly refer to anything but the *mistral* of South-eastern France.

hills near the town has proved very prejudicial to this valuable tree.

Marchand informs us that, since the felling of the woods, late spring frosts are more frequent in many localities north of the Alps; that fruit-trees thrive no longer, and that it is difficult even to raise young fruit-trees.*

Influence of the Forest, considered as Inorganic Matter, on Temperature.

The evaporation of fluids, and the condensation and expansion of vapors and gases, are attended with changes of temperature; and the quantity of moisture which the air is capable of containing, and of course, other things being equal, the evaporation, rise and fall with the thermometer. The hygroscopical and the thermoscopical conditions of the atmosphere are, therefore, inseparably connected as reciprocally dependent quantities, and neither can be fully discussed without taking notice of the other. The leaves of living trees exhale enormous quantities of gas and of aqueous vapor, and they largely absorb gases, and, under certain conditions, probably also water. Hence they affect more or less powerfully the temperature as well as the humidity of the air. But the forest, regarded purely as inorganic matter, and without reference to its living processes of absorption and exhalation of gases and of water, has, as an absorbent, a radiator and a conductor of heat, and as a mere covering of the ground, an influence on the temperature of the air and the earth, which may be considered by itself.

Absorbing and Emitting Surface.

A given area of ground, as estimated by the every-day rule of measurement in yards or acres, presents always the same apparent quantity of absorbing, radiating, and reflecting surface; but the real extent of that surface is very variable, depending, as it does, upon its configuration, and the bulk and form of the adventitious objects it bears upon it; and, besides, the true superficies remaining the same, its power of absorption, radiation, reflection, and conduction of heat will be much affected by its consistence, its greater or less humidity, and its color, as well as by its inclination of plane and exposure. An acre of clay, rolled hard and smooth, would have great reflecting power, but its radiation would be much increased by breaking it up into clods, because the actually exposed surface would be greater, though the outline of the field remained the same. The inequalities, natural or artificial, which always occur in the surface of ordinary earth, affect in the same way its quantity of superficies acting upon the temperature of the atmosphere, and acted on by it, though the amount of this action and reaction is not susceptible of measurement.

---

* *Ueber die Entwaldung der Gebirge*, p. 28.

Interesting facts and observations on this point will be found in the valuable *Report on the Effects of the Destruction of the Forests in Wisconsin*, by LAPHAM and others, pp. 6, 18, 20.

Analogous effects are produced by other objects, of whatever form or character, standing or lying upon the earth, and no solid can be placed upon a flat piece of ground, without itself exposing a greater surface than it covers. This applies, of course, to forest trees and their leaves, and indeed to all vegetables, as well as to other prominent bodies. If we suppose forty trees to be planted on an acre, one being situated in the centre of every square of two rods the side, and to grow until their branches and leaves everywhere meet, it is evident that, when in full foliage, the trunks, branches, and leaves would present an amount of thermoscopic surface much greater than that of an acre of bare earth; and besides this, the fallen leaves lying scattered on the ground, would somewhat augment the sum-total.* On the other hand, the growing leaves of trees generally form a succession of stages, or, loosely speaking, layers, corresponding to the annual growth of the branches, and more or less overlying each other. This disposition of the foliage interferes with that free communication between sun and sky above, and leaf-surface below, on which the amount of radiation and absorption of heat depends. From all these considerations, it appears that though the effective thermoscopic surface of a forest in full leaf does not exceed that of bare ground in the same proportion as does its measured superficies, yet the actual quantity of area capable of receiving and emitting heat must be greater in the former than in the latter case.*

---

* "The Washington elm at Cambridge—a tree of no extraordinary size—was some years ago estimated to produce a crop of seven millions of leaves, exposing a surface of two hundred thousand square feet, or about five acres of foliage."—GRAY, *First Lessons in Botany and Vegetable Physiology*.

It must further be remembered that the form and texture of a given surface are important elements in determining its thermoscopic character. Leaves are porous, and admit air and light more or less freely into their substance; they are generally smooth and even glazed on one surface; they are usually covered on one or both sides with spicula, and they very commonly present one or more acuminated points in their outline —all circumstances which tend to augment their power of emitting heat by reflection or radiation. Direct experiment on growing trees is very difficult, nor is it in any case practicable to distinguish how far a reduction of temperature produced by vegetation is due to radiation, and how far to exhalation of the gaseous and watery fluids of the plant; for both processes usually go on together. But the frigorific effect of leafy structure is well observed in the deposit of dew and the occurrence of hoarfrost on the foliage of grasses and other small vegetables, and on other objects of similar form and consistence, when the temperature of the air a few feet above has not been brought down to the dew-point, still less to 32°, the degree of cold required to congeal dew to frost.†

---

* See, on this particular point, and on the general influence of the forest on temperature, HUMBOLDT, *Ansichten der Natur*, i., 158.

† The leaves and twigs of plants may be reduced by radiation to a temperature lower than that of the ambient atmosphere, and even be frozen when the air in contact with them is above 32°. Their temperature may be communicated

We are also to take into account the action of the forest as a conductor of heat between the atmosphere and the earth. In the most important countries of America and Europe, and especially in those which have suffered most from the destruction of the woods, the superficial strata of the earth are colder in winter, and warmer in summer, than those a few inches lower, and their shifting temperature approximates to the atmospheric mean of the respective seasons. The roots of large trees penetrate beneath the superficial strata, and reach earth of a nearly constant temperature, corresponding to the mean for the entire year. As conductors, they convey the heat of the atmosphere to the earth when the earth is colder than the air, and transmit it in the contrary direction when the temperature of the earth is higher than that of the atmosphere. Of course, then, as conductors, they tend to equalize the temperature of the earth and the air.

In countries where the questions I am considering have the greatest practical importance, a very large proportion, if not a majority, of the trees are of deciduous foliage, and their radiating as well as their shading surface is very much greater in summer than in winter. In the latter season, they little obstruct the reception of heat by the ground or the radiation from it;

---

to the dew deposited on them and thus this dew be converted into frost when globules of watery fluid floating in the atmosphere near them, in the condition of fog or vapor, do not become congealed.

It has long been known that vegetables can be protected against frost by diffusing smoke through the atmosphere above them. This method has been lately practised in France on a large scale: vineyards of forty or fifty acres have been protected by placing one or two rows of pots of burning coal-tar, or of naphtha, along the north side of the vineyard, and thus keeping up a cloud of smoke for two or three hours before and after sunrise. The expense is said to be small, and probably it might be reduced by mixing some less combustible substance, as earth, with the fluid, and thus checking its too rapid burning.

The radiating and refrigerating power of objects by no means depends on their form alone. Melloni cut sheets of metal into the shape of leaves and grasses, and found that they produced little cooling effect, and were not moistened under atmospheric conditions which determined a plentiful deposit of dew on the leaves of vegetables.

whereas, in the former, they often interpose a complete canopy between the ground and the sky, and materially interfere with both processes.

Dead Products of Trees.

Besides this various action of standing trees, considered as inorganic matter, the forest exercises, by the annual moulting of its foliage, still another influence on the temperature of the earth, and, consequently, of the atmosphere which rests upon it. If we examine the constitution of the superficial soil in a primitive or an old and undisturbed artificially planted wood, we find, first, a deposit of undecayed leaves, twigs, and seeds, lying in loose layers on the surface; then, more compact beds of the same materials in incipient, and, as we descend, more and more advanced, stages of decomposition; then, a mass of black mould, in which traces of organic structure are hardly discoverable except by microscopic examination; then, a stratum of mineral soil, more or less mixed with vegetable matter carried down into it by water, or resulting from the decay of roots; and, finally, the inorganic earth or rock itself. Without this deposit of the dead products of trees, this latter would be the superficial stratum, and as its powers of absorption, radiation, and conduction of heat would differ essentially from those of the layers with which it has been covered by the droppings of the forest, it would act upon the temperature of the atmosphere, and be acted on by it, in a very different way from the leaves and mould which rest upon it. Dead leaves, still entire, or partially decayed, are very indifferent conductors of heat, and, therefore, though they diminish the warming influence of the summer sun on the soil below them, they, on the other hand, prevent the escape of heat from that soil in winter, and, consequently, in cold climates, even when the ground is not covered by a protecting mantle of snow, the earth does not freeze to as great a depth in the wood as in the open field.

Specific Heat.

Trees, considered as organisms, produce in themselves, or in the air, a certain amount of heat, by absorbing and condensing atmospheric gases, and they exert an opposite influence by absorbing water and exhaling it in the form of vapor; but there is still another mode by which their living processes may warm the air around them, independently of the thermometric effects of condensation and evaporation. The vital heat of a dozen persons raises the temperature of a room. If trees possess a specific temperature of their own, an organic power of generating heat like that with which the warm-blooded animals are gifted, though by a different process, a certain amount of weight is to be ascribed to this element in estimating the action of the forest upon atmospheric temperature.

Boussingault remarks: "In many flowers there has been observed a very considerable evolution of heat, at the approach of fecundation. In certain *arums* the temperature rises to 40° or 50° Cent. [= 104° or 122° Fahr.] It is very probable that this phenomenon is general, and varies only in the intensity with which it is manifested." *

If we suppose the fecundation of the flowers of forest trees to be attended with a tenth only of this calorific power, they could not fail to exert an important influence on the warmth of the atmospheric strata in contact with them.

Experiments by Meguscher, in Lombardy, led that observer to conclude "that the wood of a living tree maintains a temperature of + 12° or 13° Cent. [= 54°, 56° Fahr.] when the temperature of the air stands at 3°, 7°, and 8° [= 37°, 46°, 47° F.] above zero, and that the internal warmth of the tree does not rise and fall in proportion to that of the atmosphere. So long as the latter is below 18° [= 67° Fahr.], that of the tree is always the highest; but if the temperature of the air rises to 18°, that of the vegetable growth is the lowest. Since, then, trees maintain at all seasons a constant mean temperature of 12° [= 54° Fahr.], it is easy to see why the air in contact with the forest must be warmer in winter, cooler in summer, than in situations where it is deprived of that influence."[*]

---

* *Économie Rurale*, i., p. 22.

Professor Henry says: "As a general deduction from chemical and mechanical principles, we think no change of temperature is ever produced where the actions belonging to one or both of these principles are not present. Hence, in midwinter, when all vegetable functions are dormant, we do not believe that any heat is developed by a tree, or that its interior differs in temperature from its exterior further than it is protected from the external air. The experiments which have been made on this point, we think, have been directed by a false analogy. During the active circulation of the sap and the production of new tissue, variations of temperature belonging exclusively to the plant may be observed; but it is inconsistent with general principles that heat should be generated where no change is taking place."[†]

There can be no doubt that moisture is given out by trees and evaporated in extremely cold winter weather, and unless new fluid were supplied from the roots by the exercise of some vital function, the tree would be exhausted of its juices before winter was over. But this is not observed to be the fact, and, though the point is disputed, respectable authorities declare that "wood felled in the depth of winter is the heaviest and fullest of sap."* Warm weather in winter, of too short continuance to affect the temperature of the ground sensibly, stimulates a free flow of sap in the maple. Thus, in the last week of December, 1862, and the first week of January, 1863, sugar was made from that tree in various parts of New England. "A single branch of a tree, admitted into a warm room in winter through an aperture in a window, opened its buds and developed its leaves, while the rest of the tree in the external air remained in its winter sleep."† Like facts are matter of every-day observation in graperies where the vine is often planted outside the wall, the stem passing through an aperture into the warm interior. The roots, of course, stand in ground of the ordinary winter temperature, but vegetation is developed in the branches at the pleasure of the gardener. The roots of forest trees in temperate climates remain, for the most part, in a moist soil, of a temperature not much below the annual mean, through the whole winter; and we cannot account for the uninterrupted moisture of the tree, unless we suppose that the roots furnish a constant supply of water.

---

[*] *Memoria sur Boschi della Lombardia*, p. 45.

The results of recent experiments by Becquerel do not accord with those obtained by Meguscher, and the former eminent physicist holds that "a tree is warmed in the air like any inert body." At the same time he asserts, as a fact well ascertained by experiment, that "vegetables possess in themselves the power of resisting extreme cold for a certain length of time, ... and hence it is believed that there may exist in the organism of plants a force, independent of the conduction of caloric, which resists a degree of cold above the freezing-point." In a following page he cites observations made by Bugeaud, under the parallel of 58° N. L., between the months of November and June, during most of which time, of course, vegetable life was in its deepest lethargy. Bugeaud found that when the temperature of the air was at −34°.60, that of a poplar was only at −29°.70, which certainly confirms the doctrine that trees exercise a certain internal resistance against cold.

[†] *United States Patent Office Report* for 1857, p. 504.

Atkinson describes a ravine in a valley in Siberia, which was filled with ice to the depth of twenty-five feet. Poplars were growing in this ice, which was thawed to the distance of some inches from the stem. But the surface of the soil beneath it must have remained still frozen, for the holes around the trees were full of water resulting from its melting, and this would have escaped below if the ground had been thawed. In this case, although the roots had not thawed the thick covering of earth above them, the trunks must have melted the ice in contact with them. The trees, when observed by Atkinson, were in full leaf, but it does not appear at what period the ice around their stems had melted.

From these facts, and others of the like sort, it would seem that "all vegetable functions are" not absolutely "dormant" in winter, and, therefore, that trees may give out *some* heat even at that season.*

---

* Rossmässler, *Der Wald*, p. 158.

† Ibid., p. 160.

It does not appear that observations have been made on the special point of the development of heat in forest trees during florification, or at any other period of intense vital action; and hence an important element in the argument remains undetermined. The "circulation of the sap" commences at a very early period in the spring, and the temperature of the air in contact with trees may then be sufficiently affected by heat evolved in the vital processes of vegetation, to raise the thermometric mean of wooded countries for that season, and, of course, for the year. The determination of this point is of much greater importance to vegetable physiology than the question of the winter temperature of trees, because a slight increment of heat in the trees of a forest might so affect the atmosphere in contact with them as to make possible the growing of many plants in or near the wood which could not otherwise be reared in that climate.

---

* All evergreens, even the broad-leaved trees, resist frosts of extraordinary severity better than the deciduous trees of the same climates. Is not this because the vital processes of trees of persistent foliage are less interrupted during winter than those of trees which annually shed their leaves, and that therefore more organic heat is developed?

In crossing Mont Cenis in October, 1869, when the leaves of the larches on the northern slope and near the top of the mountain were entirely dead and turned brown, I observed that these trees were completely white with hoarfrost. It was a wonderful sight to see how every leaf was covered with a delicate deposit of frozen aqueous vapor, which gave the effect of the most brilliant silver. On the other hand, the evergreen coniferæ, which were growing among the larches, and therefore in the same conditions of exposure, were almost entirely free from frost. The contrast between the verdure of the leaves of the evergreens and the crystalline splendor of those of the larches was strikingly beautiful. Was this fact due to a difference in the color and structure of the leaves, or rather is it a proof of a vital force of resistance to cold in the living foliage of the evergreen tree?

The low temperature of air and soil at which, in the frigid zone, as well as in warmer latitudes under special circumstances, the processes of vegetation go on, seems to necessitate the supposition that all the manifestations of vegetable life are attended with an evolution of heat. In the United States it is common to protect ice, in ice-houses, by a covering of straw, which naturally sometimes contains kernels of grain. These often sprout, and even throw out roots and leaves to a considerable length, in a temperature very little above the freezing-point. Three or four years since I saw a lump of very clear and apparently solid ice, about eight inches long by six thick, on which a kernel of grain had sprouted in an ice-house, and sent half a dozen or more very slender roots into the pores of the ice and through the whole length of the lump. The young plant must have thrown out a considerable quantity of heat; for though the ice was, as I have said, otherwise solid, the pores through which the roots passed were enlarged to perhaps double the diameter of the fibres, but still not so much as to prevent the retention of water in them by capillary attraction.

The evaporation of the juices of trees and other plants is doubtless their most important thermoscopic function, and as recent observations lead to the conclusion that the quantity of moisture exhaled by vegetables has been hitherto underrated, we must ascribe to this element a higher value than has been usually assigned to it as a meteorological influence.

The exhalation and evaporation of the juices of trees, by whatever process effected, take up atmospheric heat and produce a proportional refrigeration. This effect is not less real, though to common observation less sensible, in the forest than in meadow or pasture land, and it cannot be doubted that the local temperature is considerably affected by it. But the evaporation that cools the air diffuses through it, at the same time, a medium which powerfully resists the escape of heat from the earth by radiation. Visible vapors, fogs and clouds, it is well known, prevent frosts by obstructing radiation, or rather by reflecting back again the heat radiated by the earth, just as any mechanical screen would do. On the other hand, fogs and clouds intercept the rays of the sun also, and hinder its heat from reaching the earth. The invisible vapors given out by leaves impede the passage of heat reflected and radiated by the earth and by all terrestrial objects, but oppose much less resistance to the transmission of direct solar heat, and indeed the beams of the sun seem more scorching when received through clear air charged with uncondensed moisture than after passing through a dry atmosphere. Hence the reduction of temperature by the evaporation of moisture from vegetation, though sensible, is less than it would be if water in the gaseous state were as impervious to heat given out by the sun as to that emitted by terrestrial objects.

Total Influence of the Forest on Temperature.

It has not yet been found practicable to measure, sum up, and equate the total influence of the forest, its processes and its products, dead and living, upon temperature, and investigators differ much in their conclusions on this subject. It seems probable that in every particular case the result is, if not determined, at least so much modified by local conditions which are infinitely varied, that no general formula is applicable to the question.

In the report to which I referred on page 163, Gay-Lussac says: "In my opinion we have not yet any positive proof that the forest has, in itself, any real influence on the climate of a great country, or of a particular locality. By closely examining the effects of clearing off the woods, we should perhaps find that, far from being an evil, it is an advantage; but these questions are so complicated when they are examined in a climatological point of view, that the solution of them is very difficult, not to say impossible."

Becquerel, on the other hand, considers it certain that in tropical climates the destruction of the forests is accompanied with an elevation of the mean temperature, and he thinks it highly probable that it has the same effect in the temperate zones. The following is the substance of his remarks on this subject:

"Forests act as frigorific causes in three ways:

"1. They shelter the ground against solar irradiation and maintain a greater humidity.

"2. They produce a cutaneous transpiration by the leaves.

"3. They multiply, by the expansion of their branches, the surfaces which are cooled by radiation.

"These three causes acting with greater or less force, we must, in the study of the climatology of a country, take into account the proportion between the area of the forests and the surface which is bared of trees and covered with herbs and grasses.

"We should be inclined to believe, *à priori*, according to the foregoing considerations, that the clearing of the woods, by raising the temperature and increasing the dryness of the air, ought to react on climate. There is no doubt that, if the vast desert of the Sahara were to become wooded in the course of ages, the sands would cease to be heated as much as at the present epoch, when the mean temperature is twenty-nine degrees [Centigrade, = 85° Fahr.]. In that case, the ascending currents of warm air would cease, or be less warm, and would not contribute, by descending in our latitudes, to soften the climate of Western Europe. Thus the clearing of a great country may react on the climates of regions more or less remote from it.

"The observations by Boussingault leave no doubt on this point. This writer determined the mean temperature of wooded and of cleared points, under the same latitude, and at the same elevation above the sea, in localities comprised between the eleventh degree of north and the fifth degree of south latitude, that is to say, in the portion of the tropics nearest to the equator, and where radiation tends powerfully during the night to lower the temperature under a sky without clouds." *

The result of these observations, which has been pretty generally adopted by physicists, is that the mean temperature of cleared land in the tropics appears to be about one degree Centigrade, or a little less than two degrees of Fahrenheit, above that of the forest. On page 147 of the volume just cited, Becquerel argues that, inasmuch as the same and sometimes a greater difference is found in favor of the open ground, at points within the tropics so elevated as to have a temperate or even a polar climate, we must conclude that the forests in Northern America exert a refrigerating influence equally powerful. But the conditions of the soil are so different in the two regions compared, that I think we cannot, with entire confidence, reason from the one to the other, and it is much to be desired that observations be made on the summer and winter temperature of both the air and the ground in the depths of the North American forests, before it is too late.

---

* BECQUEREL, *Des Climats*, etc., pp. 139–141.

Recent inquiries have introduced a new element into the problem of the influence of the forest on temperature, or rather into the question of the thermometrical effects of its destruction. I refer to the composition of the soil in respect to its hygroscopicity or aptitude to absorb humidity, whether in a liquid or a gaseous form, and to the conducting power of the particles of which it is composed.*

---

* Composition, texture, and color of soil are important elements to be considered in estimating the effects of the removal of the forest upon its thermoscopic action. "Experience has proved," says Becquerel, "that when the soil is bared, it becomes more or less heated [by the rays of the sun] according to the nature and the color of the particles which compose it, and according to its humidity, and that, in the refrigeration resulting from radiation, we must take into the account the conducting power of those particles also. Other things being equal, siliceous and calcareous sands, compared in equal volumes with different argillaceous earths, with calcareous powder or dust, with humus, with arable and with garden earth, are the soils which least conduct heat. It is for this reason that sandy ground, in summer, maintains a high temperature even during the night. We may hence conclude that when a sandy soil is stripped of wood, the local temperature will be raised. After the sands follow successively argillaceous, arable, and garden ground, then humus, which occupies the lowest rank.

"The retentive power of humus is but half as great as that of calcareous sand. We will add that the power of retaining heat is proportional to the density. It has also a relation to the magnitude of the particles. It is for this reason that ground covered with siliceous pebbles cools more slowly than siliceous sand, and that pebbly soils are best suited to the cultivation of the vine, because they advance the ripening of the grape more rapidly than chalky and clayey earths, which cool quickly. Hence we see that in examining the calorific effects of clearing forests, it is important to take into account the properties of the soil laid bare."—BECQUEREL, *Des Climats et des Sols boisés*, p. 137.

The hygroscopicity of humus or vegetable earth is much greater than that of any mineral soil, and consequently forest ground, where humus abounds, absorbs the moisture of the atmosphere more rapidly and in larger proportion than common earth. The condensation of vapor by absorption develops heat, and consequently elevates the temperature of the soil which absorbs it, together with that of air in contact with the surface. Von Babo found the temperature of sandy ground thus raised from 68° to 80° F., that of soil rich in humus from 68° to 88°.

The question of the influence of the woods on temperature does not, in the present state of our knowledge, admit of precise solution, and, unhappily, the primitive forests are disappearing so rapidly before the axe of the woodman, that we shall never be able to estimate with accuracy the climatological action of the natural wood, though all the physical functions of artificial plantations will, doubtless, one day be approximately known.

But the value of trees as a mechanical screen to the soil they cover, and often to ground far to the leeward of them, is most abundantly established, and this agency alone is important enough to justify extensive plantation in all countries which do not enjoy this indispensable protection.

Influence of Forests as Inorganic on the Humidity of the Air and the Earth.

The most important hygroscopic as well as thermoscopic influence of the forest is, no doubt, that which it exercises on the humidity of the air and the earth, and this climatic action it exerts partly as dead, partly as living matter. By its interposition as a curtain between the sky and the ground it both checks evaporation from the earth, and mechanically intercepts a certain proportion of the dew and the lighter showers, which would otherwise moisten the surface of the soil, and restores it to the atmosphere by exhalation;* while in heavier rains, the large drops which fall upon the leaves and branches are broken into smaller ones, and consequently strike the ground with less mechanical force, or are perhaps even dispersed into vapor without reaching it.†

---

* Mangotti had observed and described, in his usual picturesque way, the retention of rain-water by the foliage and bark of trees, but I do not know that any attempts were made to measure the quantity thus intercepted before the experiments of Becquerel, communicated to the Academy of Sciences in 1866. These experiments embraced three series of observations continued respectively for periods of a year, a month, and two days. According to Becquerel's measurements, the quantity falling on bare and on wooded soil respectively was as 1 to 0.67; 1 to 0.5; and 1 to 0.6, or, in other words, he found that only from five-tenths to sixty-seven hundredths of the precipitation reached the ground.—*Comptes Rendus de l'Académie des Sciences*, 1866.

It seemed, indeed, improbable that in rain-storms which last not hours but whole days in succession, so large a proportion of the downfall should continue to be intercepted by forest vegetation after the leaves, the bark, and the whole framework of the trees were thoroughly wet, but the conclusions of this eminent physicist appear to have been generally accepted until the very careful experiments of Mathieu at the Forest-School of Nancy were made known. The observations of Mathieu were made in a plantation of deciduous trees forty-two years old, and were continued through the entire years 1866, 1867, and 1868. The result was that the precipitation in the wood was to that in an open glade of several acres near the forest station as 943 to 1,000, and the proportion in each of the three years was nearly identical. According to Mathieu, then, only 57 thousandths or 5.7 per cent. of the precipitation is intercepted by trees.—SURELL, *Étude sur les Torrents*, 2d ed., ii., p. 98.

By order of the Direction of the Forests of the Canton of Berne, a series of experiments on this subject was commenced at the beginning of the year 1869. During the first seven months of the year (the reports for which alone I have seen), including, of course, the season when the foliage is most abundant, as well as that when it is thinnest, the pluviometers in the woods received only fifteen per cent. less than those in the open grounds in the vicinity.—RISLER, in *Revue des Eaux et Forêts*, of 10th January, 1870.

† We are not, indeed, to suppose that the condensation of vapor and the evaporation of water are going on in the same stratum of air at the same time, or, in other words, that vapor is condensed into rain-drops, and rain-drops evaporated, under the same conditions; but rain formed in one stratum may fall through another, where vapor would not be condensed. Two saturated strata of different temperatures may be brought into contact in the higher regions, and discharge large rain-drops, which, if not divided by some obstruc-

The vegetable mould, resulting from the decomposition of leaves and of wood, serves as a perpetual *mulch* to forest-soil by carpeting the ground with a spongy covering which obstructs the evaporation from the mineral earth below,* drinks up the rains and melting snows that would otherwise flow rapidly over the surface and perhaps be conveyed to the distant sea, and then slowly gives out, by evaporation, infiltration, and percolation, the moisture thus imbibed. The roots, too, penetrate far below the superficial soil, conduct water along their surface to the lower depths to which they reach, and thus by partially draining the superior strata, remove a certain quantity of moisture out of the reach of evaporation.

The Forest as Organic.

These are the principal modes in which the humidity of the atmosphere is affected by the forest regarded as lifeless matter. Let us inquire how its organic processes act upon this meteorological element.

The commonest observation shows that the wood and bark of living trees are always more or less pervaded with watery and other fluids, one of which, the sap, is very abundant in trees of deciduous foliage when the buds begin to swell and the leaves to develop themselves in the spring. This fluid is drawn principally, if not entirely, from the ground by the absorbent action of the roots, for though Schacht and some other eminent botanical physiologists have maintained that water is absorbed by the leaves and bark of trees, yet most experiments lead to the con-

---

tion, will reach the ground, though passing through strata which would vaporize them if they were in a state of more minute division.

* The only direct experiments known to me on the evaporation from the *surface* of the forest are those of Mathieu.—SURELL, *Étude sur les Torrents*, 2d ed., ii., p. 99.

These experiments were continued from March to December, inclusive, of the year 1868. It was found that during those months the evaporation from a recipient placed on the ground in a plantation of deciduous trees sixty-two years old, was less than one-fifth of that from a recipient of like form and dimensions placed in the open country.

trary result, and it is now generally held that no water is taken in by the pores of vegetables. Late observations by Cailletet in France, however, tend to the establishment of a new doctrine on this subject which solves many difficulties and will probably be accepted by botanists as definitive. Cailletet finds that under normal conditions, that is, when the soil is humid enough to supply sufficient moisture through the roots, no water is absorbed by the leaves, buds, or bark of plants, but when the roots are unable to draw from the earth the requisite quantity of this fluid, the vegetable pores in contact with the atmosphere absorb it from that source.

Popular opinion, indeed, supposes that all the vegetable fluids, during the entire period of growth, are drawn from the bosom of the earth, and that the wood and other products of the tree are wholly formed from matter held in solution in the water abstracted by the roots from the ground. This is an error, for the solid matter of the tree, in a certain proportion not important to our present inquiry, is received from the atmosphere in a gaseous form, through the pores of the leaves and of the young shoots, and, as we have just seen, moisture is sometimes supplied to trees by the atmosphere. The amount of water taken up by the roots, however, is vastly greater than that imbibed through the leaves and bark, especially at the season when the sap is most abundant, and when the leaves are yet in embryo. The quantity of water thus received from the air and the earth, in a single year, even by a wood of only a hundred acres, is very great, though experiments are wanting to furnish the data for even an approximate estimate of its measure; for only the vaguest conclusions can be drawn from the observations which have been made on the imbibition and exhalation of water by trees and other plants reared in artificial conditions diverse from those of the natural forest.*

---

* The experiments of Hales and others on the absorption and exhalation of vegetables are of high physiological interest; but observations on sunflowers, cabbages, hops, and single branches of isolated trees, growing in artificially prepared soils and under artificial conditions, furnish no trustworthy data for computing the quantity of water received and given off by the natural wood.

The vegetable mould, resulting from the decomposition of leaves and of wood, serves as a perpetual *mulch* to forest-soil by carpeting the ground with a spongy covering which obstructs the evaporation from the mineral earth below,* drinks up the rains and melting snows that would otherwise flow rapidly over the surface and perhaps be conveyed to the distant sea, and then slowly gives out, by evaporation, infiltration, and percolation, the moisture thus imbibed. The roots, too, penetrate far below the superficial soil, conduct water along their surface to the lower depths to which they reach, and thus by partially draining the superior strata, remove a certain quantity of moisture out of the reach of evaporation.

The Forest as Organic.

These are the principal modes in which the humidity of the atmosphere is affected by the forest regarded as lifeless matter. Let us inquire how its organic processes act upon this meteorological element.

The commonest observation shows that the wood and bark of living trees are always more or less pervaded with watery and other fluids, one of which, the sap, is very abundant in trees of deciduous foliage when the buds begin to swell and the leaves to develop themselves in the spring. This fluid is drawn principally, if not entirely, from the ground by the absorbent action of the roots, for though Schacht and some other eminent botanical physiologists have maintained that water is absorbed by the leaves and bark of trees, yet most experiments lead to the con-

---

tion, will reach the ground, though passing through strata which would vaporize them if they were in a state of more minute division.

* The only direct experiments known to me on the evaporation from the *surface* of the forest are those of Mathieu.—SURELL, *Étude sur les Torrents*, 2d ed., ii., p. 99.

These experiments were continued from March to December, inclusive, of the year 1868. It was found that during those months the evaporation from a recipient placed on the ground in a plantation of deciduous trees sixty-two years old, was less than one-fifth of that from a recipient of like form and dimensions placed in the open country.

trary result, and it is now generally held that no water is taken in by the pores of vegetables. Late observations by Cailletet in France, however, tend to the establishment of a new doctrine on this subject which solves many difficulties and will probably be accepted by botanists as definitive. Cailletet finds that under normal conditions, that is, when the soil is humid enough to supply sufficient moisture through the roots, no water is absorbed by the leaves, buds, or bark of plants, but when the roots are unable to draw from the earth the requisite quantity of this fluid, the vegetable pores in contact with the atmosphere absorb it from that source.

Popular opinion, indeed, supposes that all the vegetable fluids, during the entire period of growth, are drawn from the bosom of the earth, and that the wood and other products of the tree are wholly formed from matter held in solution in the water abstracted by the roots from the ground. This is an error, for the solid matter of the tree, in a certain proportion not important to our present inquiry, is received from the atmosphere in a gaseous form, through the pores of the leaves and of the young shoots, and, as we have just seen, moisture is sometimes supplied to trees by the atmosphere. The amount of water taken up by the roots, however, is vastly greater than that imbibed through the leaves and bark, especially at the season when the sap is most abundant, and when the leaves are yet in embryo. The quantity of water thus received from the air and the earth, in a single year, even by a wood of only a hundred acres, is very great, though experiments are wanting to furnish the data for even an approximate estimate of its measure; for only the vaguest conclusions can be drawn from the observations which have been made on the imbibition and exhalation of water by trees and other plants reared in artificial conditions diverse from those of the natural forest.*

---

* The experiments of Hales and others on the absorption and exhalation of vegetables are of high physiological interest; but observations on sunflowers, cabbages, hops, and single branches of isolated trees, growing in artificially prepared soils and under artificial conditions, furnish no trustworthy data for computing the quantity of water received and given off by the natural wood.

The sap of the maple, and of other trees with deciduous leaves which grow in the same climate, flows most freely in the early spring, and especially in clear weather, when the nights are frosty and the days warm; for it is then that the melting snows supply the earth with moisture in the justest proportion, and that the absorbent power of the roots is stimulated to its highest activity.

When the buds are ready to burst, and the green leaves begin to show themselves beneath their scaly covering, the ground has become drier, the absorption by the roots is diminished, and the sap, being immediately employed in the formation of the foliage, can be extracted from the stem in only small quantities.

Absorption and Exhalation by Foliage.

The leaves now commence the process of absorption, and imbibe both uncombined gases and an unascertained but probably inconsiderable quantity of aqueous vapor from the humid atmosphere of spring which bathes them.

The organic action of the tree, as thus far described, tends to the desiccation of air and earth; but when we consider what volumes of water are daily absorbed by a large tree, and how small a proportion of the weight of this fluid consists of matter which, at the period when the flow of sap is freest, enters into new combinations, and becomes a part of the solid framework of the vegetable, or a component of its deciduous products, it becomes evident that the superfluous moisture must somehow be carried back again almost as rapidly as it flows into the tree. At the very commencement of vegetation in spring, some of this fluid certainly escapes through the buds, the nascent foliage, and the pores of the bark, and vegetable physiology tells us that there is a current of sap towards the roots as well as from them.* I do not know that the exudation of water into the earth, through the bark or at the extremities of these latter organs, has been proved, but the other known modes of carrying off the surplus do not seem adequate to dispose of it at the almost leafless period when it is most abundantly received, and it is possible that the roots may, to some extent, drain as well as flood the water-courses of their stem. Later in the season the roots absorb less, and the now developed leaves exhale an increased quantity of moisture into the air. In any event, all the water derived by the growing tree from the atmosphere and the ground is parted with by transpiration or exudation, after having surrendered to the plant the small proportion of matter required for vegetable growth which it held in solution or suspension.* The hygrometrical equilibrium is then restored, so far as this: the tree yields up again the moisture it had drawn from the earth and the air, though it does not return it

---

* "The elaborated sap, passing out of the leaves, is received into the inner bark, * * * and a part of what descends finds its way even to the ends of the roots, and is all along diffused laterally into the stem, where it meets and mingles with the ascending crude sap or raw material. So there is no separate cir-

---

culation of the two kinds of sap; and no crude sap exists separately in any part of the plant. Even in the root, where it enters, this mingles at once with some elaborated sap already there."—GRAY, *How Plants Grow*, § 273.

* Ward's tight glazed cases for raising and especially for transporting plants, go far to prove that water only circulates through vegetables, and is again and again absorbed and transpired by organs appropriated to these functions. Seeds, growing grasses, shrubs, or trees planted in proper earth, moderately watered and covered with a glass bell or close frame of glass, live for months, and even years, with only the original store of air and water. In one of Ward's early experiments, a spire of grass and a fern, which sprang up in a corked bottle containing a little moist earth introduced as a bed for a snail, lived and flourished for eighteen years without a new supply of either fluid. In these boxes the plants grow till the enclosed air is exhausted of the gaseous constituents of vegetation, and till the water has yielded up the assimilable matter it held in solution, and dissolved and supplied to the roots the nutriment contained in the earth in which they are planted. After this, they continue for a long time in a state of vegetable sleep, but if fresh air and water be introduced into the cases, or the plants be transplanted into open ground, they rouse themselves to renewed life, and grow vigorously, without appearing to have suffered from their long imprisonment. The water transpired by the leaves is partly absorbed by the earth directly from the air, partly condensed on the glass, along which it trickles down to the earth, enters the roots again, and thus continually repeats the circuit. See *Aus der Natur*, 21, B. S. 537.

each to each; for the vapor carried off by transpiration greatly exceeds the quantity of water absorbed by the foliage from the atmosphere, and the amount, if any, carried back to the ground by the roots.

The present estimates of some eminent vegetable physiologists in regard to the quantity of aqueous vapor exhaled by trees and taken up by the atmosphere are much greater than those of former inquirers. Direct and satisfactory experiments on this point are wanting, and it is not easy to imagine how they could be made on a sufficiently extensive and comprehensive scale. Our conclusions must therefore be drawn from observations on small plants, or separate branches of trees, and of course are subject to much uncertainty. Nevertheless, Schleiden, arguing from such analogies, comes to the surprising result, that a wood evaporates ten times as much water as it receives from atmospheric precipitation.[*] In the Northern and Eastern States of the Union, the mean precipitation during the period of forest growth, that is from the swelling of the buds in the spring to the ripening of the fruit, the hardening of the young shoots, and the full perfection of the other annual products of the tree, exceeds on the average twenty-four inches. Taking this estimate, the evaporation from the forest would be equal to a precipitation of two hundred and forty inches, or very nearly one hundred and fifty standard gallons to the square foot of surface.

The first questions which suggest themselves upon this statement are: what becomes of this immense quantity of water and from what source does the tree derive it? We are told in reply that it is absorbed from the air by the humus and mineral soil of the wood, and supplied again to the tree through its roots, by a circulation analogous to that observed in Ward's air-tight cases.

---

[*] *Für Baum und Wald*, pp. 46, 47, *notes*. Pfaff, too, experimenting on branches of a living oak, weighed immediately after being cut from the tree, and again after an exposure to the air for three minutes, and computing the superficial measure of all the leaves of the tree, concludes that an oak-tree evaporates, during the season of growth, eight and a half times the mean amount of rain-fall on an area equal to that shaded by the tree.

When we recall the effect produced on the soil even of a thick wood by a rain-fall of one inch, we find it hard to believe that two hundred and forty times that quantity, received by the ground between early spring and autumn, would not keep it in a state of perpetual saturation, and speedily convert the forest into a bog.

No such power of absorption of moisture by the earth from the atmosphere, or anything approaching it, has ever been shown by experiment, and all scientific observation contradicts the supposition. Schübler found that in seventy-two hours thoroughly dried humus, which is capable of taking up twice its own weight of water in the liquid state, absorbed from the atmosphere only twelve per cent. of its weight of humidity; garden-earth five and one-fifth per cent. and ordinary cultivated soil two and one-third per cent. After seventy-two hours, and, in most of his experiments with thirteen different earths, after forty-eight hours, no further absorption took place. Wilhelm, experimenting with air-dried field-earth, exposed to air in contact with water and protected by a bell-glass, found that the absorption amounted in seventy-two hours to two per cent. and a very small fraction, nearly the whole of which was taken up in the first forty-eight hours. In other experiments with carefully heat-dried field-soil, the absorption was five per cent. in eighty-four hours, and when the water was first warmed to secure the complete saturation of the air, air-dried garden-earth absorbed five and one-tenth per cent. in seventy-two hours.

In nature, the conditions are never so favorable to the absorption of vapor as in these experiments. The ground is more compact and of course offers less surface to the air, and, especially in the wood, it is already in a state approaching saturation. Hence, both these physicists conclude that the quantity of aqueous vapor absorbed by the earth from the air is so inconsiderable "that we can ascribe to it no important influence on vegetation." *

---

* WILHELM, *Der Boden und das Wasser*, pp. 14, 20.

Besides this, trees often grow luxuriantly on narrow ridges, on steep declivities, on partially decayed stumps many feet above the ground, on walls of high buildings, and on rocks, in situations where the earth within reach of their roots could not possibly contain the tenth part of the water which, according to Schleiden and Pfaff, they evaporate in a day. There are, too, forests of great extent on high bluffs and well-drained table-lands, where there can exist, neither in the subsoil nor in infiltration from neighboring regions, an adequate source of supply for such consumption. It must be remembered, also, that in the wood the leaves of the trees shade each other, and only the highest stratum of foliage receives the full influence of heat and light; and besides, the air in the forest is almost stagnant, while in the experiments of Unger, Marshal, Vaillant, Pfaff and others, the branches were freely exposed to light, sun, and atmospheric currents. Such observations can authorize no conclusions respecting the quantitative action of leaves of forest trees in normal conditions.

Further, allowing two hundred days for the period of forest vital action, the wood must, according to Schleiden's position, exhale a quantity of moisture equal to an inch and one-fifth of precipitation per day, and it is hardly conceivable that so large a volume of aqueous vapor, in addition to the supply from other sources, could be diffused through the ambient atmosphere without manifesting its presence by ordinary hygrometrical tests much more energetically than it has been proved to do, and in fact, the observations recorded by Ebermayer show that though the *relative* humidity of the atmosphere is considerably greater in the cooler temperature of the wood, its *absolute* humidity does not sensibly differ from that of the air in open ground.[*]

---

[*] EBERMAYER, *Die Physikalischen Einwirkungen des Waldes*, i., pp. 150 *et seqq.* It may be well here to guard my readers against the common error which supposes that a humid condition of the *air* is necessarily indicated by the presence of fog or visible vapor. The air is rendered humid by containing *invisible* vapor, and it becomes drier by the condensation of such vapor into fog, composed of solid globules or of hollow vesicles of water—for it is a disputed point whether the particles of fog are solid or vesicular. Hence,

The daily discharge of a quantity of aqueous vapor corresponding to a rain-fall of one inch and a fifth into the cool air of the forest would produce a perpetual shower, or at least drizzle, unless, indeed, we suppose a rapidity of absorption and condensation by the ground, and of transmission through the soil to the roots and through them and the vessels of the tree to the leaves, much greater than has been shown by direct observation. Notwithstanding the high authority of Schleiden, therefore, it seems impossible to reconcile his estimates with facts commonly observed and well established by competent investigators. Hence the important question of the supply, demand, and expenditure of water by forest vegetation must remain undecided, until it can be determined by something approaching to satisfactory direct experiment.[*]

Balance of Conflicting Influences of Forest on Atmospheric Heat and Humidity.

We have shown that the forest, considered as dead matter, tends to diminish the moisture of the air, by preventing the sun's rays from reaching the ground and evaporating the water that falls upon the surface, and also by spreading over the earth a spongy mantle which sucks up and retains the humidity it receives from the atmosphere, while, at the same time, this covering acts in the contrary direction by accumulating, in a reservoir not wholly inaccessible to vaporizing influences, the water of precipitation which might otherwise suddenly sink deep into the bowels of the earth, or flow by superficial channels to other climatic regions. We now see that, as a living organism, it

---

though the ambient atmosphere may hold in suspension, in the form of fog, water enough to obscure its transparency, and to produce the sensation of moisture on the skin, the *air*, in which the finely divided water floats, may be charged with even less than an average proportion of humidity.

[*] According to Cezanne, SURELL, *Étude sur les Torrents*, 2e édition, ii., p. 100, experiments reported in the *Revue des Eaux et Forêts* for August, 1868, showed the evaporation from a living tree to be "almost insignificant." Details are not given.

tends, on the one hand, to diminish the humidity of the air by sometimes absorbing moisture from it, and, on the other, to increase that humidity by pouring out into the atmosphere, in a vaporous form, the water it draws up through its roots This last operation, at the same time, lowers the temperature of the air in contact with or proximity to the wood, by the same law as in other cases of the conversion of water into vapor.

As I have repeatedly said, we cannot measure the value of any one of these elements of climatic disturbance, raising or lowering of temperature, increase or diminution of humidity, nor can we say that in any one season, any one year, or any one fixed cycle, however long or short, they balance and compensate each other. They are sometimes, but certainly not always, contemporaneous in their action, whether their tendency is in the same or in opposite directions, and, therefore, their influence is sometimes cumulative, sometimes conflicting; but, upon the whole, their general effect is to mitigate extremes of atmospheric heat and cold, moisture and drought. They serve as equalizers of temperature and humidity, and it is highly probable that, in analogy with most other works and workings of nature, they, at certain or uncertain periods, restore the equilibrium which, whether as lifeless masses or as living organisms, they may have temporarily disturbed.*

---

* There is one fact which I have nowhere seen noticed, but which seems to me to have an important bearing on the question whether forests tend to maintain an equilibrium between the various causes of hygroscopic action, and consequently to keep the air within their precincts in an approximately constant condition, so far as this meteorological element is concerned. I refer to the absence of fog or visible vapor in thick woods in full leaf, even when the air of the neighboring open grounds is so heavily charged with condensed vapor as completely to obscure the sun. The temperature of the atmosphere in the forest is not subject to so sudden and extreme variations as that of cleared ground, but at the same time it is far from constant, and so large a supply of vapor as is poured out by the foliage of the trees could not fail to be sometimes condensed into fog by the same causes as in the case of the adjacent meadows, which are often covered with a dense mist while the forest-air remains clear, were there not some potent counteracting influence always in action. This influence, I believe, is to be found partly in the equalization of the temperature of the forest, and partly in the balance be-

When, therefore, man destroys these natural harmonizers of climatic discords, he sacrifices an important conservative power, though it is far from certain that he has thereby affected the mean, however much he may have exaggerated the extremes of atmospheric temperature and humidity, or, in other words, may have increased the range and lengthened the scale of thermometric and hygrometric variation.

Special Influence of Woods on Precipitation.

With the question of the action of forests upon temperature and upon atmospheric humidity is intimately connected that of their influence upon precipitation, which they may affect by increasing or diminishing the warmth of the air and by absorbing or exhaling uncombined gas and aqueous vapor. The forest being a natural arrangement, the presumption is that it exercises a conservative action, or at least a compensating one, and consequently that its destruction must tend to produce pluviometrical disturbances as well as thermometrical variations. And this is the opinion of perhaps the greatest number of observers. Indeed, it is almost impossible to suppose that, under certain conditions of time and place, the quantity and the periods of rain should not depend, more or less, upon the presence or absence of forests; and without insisting that the removal of the forest has diminished the sum-total of snow and rain, we may well admit that it has lessened the quantity which annually falls within particular limits. Various theoretical considerations make this probable, the most obvious argument, perhaps, being that drawn from the generally admitted fact, that the summer and even the mean temperature of the forest is below that of the open country in the same latitude. If the air in a wood is cooler than that around it, it must reduce the temperature of the atmospheric stratum immediately above it, and, of course, whenever a satu-

---

tween the humidity exhaled by the trees and that absorbed and condensed invisibly by the earth.

rated current sweeps over it, it must produce precipitation which would fall upon it, or at a greater or less distance from it.

We must here take into the account a very important consideration. It is not universally or even generally true, that the atmosphere returns its condensed humidity to the local source from which it receives it. The air is constantly in motion,

> —— howling tempests scour amain
> From sea to land, from land to sea; *

and, therefore, it is always probable that the evaporation drawn up by the atmosphere from a given river, or sea, or forest, or meadow, will be discharged by precipitation, not at or near the point where it rose, but at a distance of miles, leagues, or even degrees. The currents of the upper air are invisible, and they leave behind them no landmark to record their track. We know not whence they come, or whither they go. We have a certain rapidly increasing acquaintance with the laws of general atmospheric motion, but of the origin and limits, the beginning and end of that motion, as it manifests itself at any particular time and place, we know nothing. We cannot say where or when the vapor, exhaled to-day from the lake on which we float, will be condensed and fall; whether it will waste itself on a barren desert, refresh upland pastures, descend in snow on Alpine heights, or contribute to swell a distant torrent which shall lay waste square miles of fertile corn-land; nor do we know whether the rain which feeds our brooklets is due to the transpiration from a neighboring forest, or to the evaporation from a far-off sea. If, therefore, it were proved that the annual quantity of rain and dew is now as great on the plains of Castile, for example, as it was when they were covered with the native forest, it would by no means follow that those woods did not augment the amount of precipitation elsewhere.

---

* Und Stürme brausen um die Wette
Vom Meer aufs Land, vom Land aufs Meer.
GOETHE, *Faust, Song of the Archangels.*

The whole problem of the pluviometrical influence of the forest, general or local, is so exceedingly complex and difficult that it cannot, with our present means of knowledge, be decided upon *à priori* grounds. It must now be regarded as a question of fact which would probably admit of scientific explanation if it were once established what the actual fact is. Unfortunately, the evidence is conflicting in tendency, and sometimes equivocal in interpretation, but I believe that a majority of the foresters and physicists who have studied the question are of opinion that in many, if not in all cases, the destruction of the woods has been followed by a diminution in the annual quantity of rain and dew. Indeed, it has long been a popularly settled belief that vegetation and the condensation and fall of atmospheric moisture are reciprocally necessary to each other, and even the poets sing of

> Afric's barren sand,
> Where nought can grow, because it raineth not,
> And where no rain can fall to bless the land,
> Because nought grows there. *

Before going further with the discussion, however, it is well to remark that the comparative rarity or frequency of inundations in earlier or later centuries is not necessarily, in most cases not probably, entitled to any weight whatever, as a proof that more or less rain fell formerly than now; because the accumulation of water in the channel of a river depends far less upon the quantity of precipitation in its valley, than upon the rapidity with which it is conducted, on or under the surface of the ground, to the central artery that drains the basin. But this point will be more fully discussed in a subsequent chapter.

In writers on the subject we are discussing, we find many positive assertions about the diminution of rain in countries which have been stripped of wood within the historic period, but these assertions very rarely rest upon any other proof than the doubtful recollection of unscientific observers, and I am unable to refer to a single instance where the records of the rain-gauge, for a considerable period before and after the felling or planting of extensive woods, can be appealed to in support of either side of the question. The scientific reputation of many writers who have maintained that precipitation has been diminished in particular localities by the destruction of forests, or augmented by planting them, has led the public to suppose that their assertions rested on sufficient proof. We cannot affirm that in none of these cases did such proof exist, but I am not aware that it has ever been produced.[*]

---

* —— Det golde Strög i Afrika,
Der Intet voxe kan, da ei det regner,
Og, omvendt, ingen Regn kan falde, da
Der Intet voxer.
PALUDAN-MÜLLER, *Adam Homo*, ii., 408.

The effect of the forest on precipitation, then, is by no means free from doubt, and we cannot positively affirm that the total annual quantity of rain is even locally diminished or increased by the destruction of the woods, though both theoretical considerations and the balance of testimony strongly favor the opinion that more rain falls in wooded than in open countries. One important conclusion, at least, upon the meteorological influence of forests is certain and undisputed: the proposition, namely, that, within their own limits, and near their own borders, they maintain a more uniform degree of humidity in the atmosphere than is observed in cleared grounds. Scarcely less can it be questioned that they tend to promote the frequency of showers, and, if they do not augment the amount of precipitation, they probably equalize its distribution through the different seasons.*

---

[*] Among recent writers, Clavé, Schacht, Sir John F. W. Herschel, Hohenstein, Barth, Asbjörnsen, Boussingault, and others, maintain that forests tend to produce rain and clearings to diminish it, and they refer to numerous facts of observation in support of this doctrine; but in none of these does it appear that these observations are supported by actual pluviometrical measure. So far as I know, the earliest expression of the opinion that forests promote precipitation is that attributed to Christopher Columbus, in the *Historie del S. D. Fernando Colombo*, Venetia, 1571, cap. lviii., where it is said that the Admiral ascribed the daily showers which fell in the West Indies about vespers to "the great forests and trees of those countries," and remarked that the same effect was formerly produced by the same cause in the Canary and Madeira islands and in the Azores, but that "now that the many woods and trees that covered them have been felled, there are not produced so many clouds and rains as before."

Mr. H. Harrisse, in his very learned and able critical essay, *Fernand Colomb, sa Vie et ses Œuvres*, Paris, 1872, has made it at least extremely probable that the *Historie* is a spurious work. The compiler may have found this observation in some of the writings of Columbus now lost, but however that may be, the fact, which Humboldt mentions in *Cosmos* with much interest, still remains, that the doctrine in question was held, if not by the great discoverer himself, at least by one of his pretended biographers, as early as the year 1571.

---

* The strongest direct evidence which I am able to refer to in support of the proposition that the woods produce even a local augmentation of precipitation is furnished by the observations of Mathieu, sub-director of the Forest-School at Nancy. His pluviometrical measurements, continued for three years, 1866–1868, show that during that period the annual mean of rain-fall in the centre of the wooded district of Cinq-Tranchées, at Belle Fontaine on the borders of the forest, and at Amance, in an open cultivated territory in the same vicinity, was respectively as the numbers 1,000, 957, and 853.

The alleged augmentation of rain-fall in Lower Egypt, in consequence of large plantations by Mehemet Ali, is very frequently appealed to as a proof of this influence of the forest, and this case has become a regular common-place in all discussions of the question. It is, however, open to the same objection as the alleged instances of the diminution of precipitation in consequence of the felling of the forest.

This supposed increase in the frequency and quantity of rain in Lower Egypt is, I think, an error, or at least not an established fact. I have heard it disputed on the spot by intelligent Franks, whose residence in that country began before the plantations of Mehemet Ali and Ibrahim Pacha, and I have been assured by them that meteorological observations, made at Alexandria about the beginning of this century, show an annual fall of rain as great as is usual at this day. The mere fact that it did not rain during the French occupation is not conclusive. Having experienced a gentle shower of nearly twenty-four hours' duration in Upper Egypt, I inquired of the local governor in relation to the frequency of this phenomenon, and was told by him that not a drop of rain had fallen at that point for more than two years previous.

The belief in the increase of rain in Egypt rests almost entirely on the observations of Marshal Marmont, and the evidence collected by him in 1836. His conclusions have been disputed, if not confuted, by Jomard and others,

Total Climatic Influence of the Forest.

Aside from the question of local disturbances and their compensations, it does not seem probable that the forests sensibly affect the general mean of atmospheric temperature of the globe, or the total quantity of precipitation, or even that they had this influence when their extent was vastly greater than at present. The waters cover about three-fourths of the face of the earth, and if we deduct the frozen zones, the peaks and crests of lofty mountains and their craggy slopes, the Sahara and other great African and Asiatic deserts, and all such other portions of the solid surface as are permanently unfit for the growth of wood, we shall find that probably not one-tenth of the total superficies of our planet was ever, at any one time in

---

and are probably erroneous. See FOISSAC, *Météorologie*, German translation, pp. 634–639.

It certainly sometimes rains briskly at Cairo, but evaporation is exceedingly rapid in Egypt—as any one who ever saw a Fellah woman wash a napkin in the Nile, and dry it by shaking it a few moments in the air, can testify; and a heap of grain, wet a few inches below the surface, would probably dry again without injury. At any rate, the Egyptian Government often has vast quantities of wheat stored at Boulak in uncovered yards through the winter, though it must be admitted that the slovenliness and want of foresight in Oriental life, public and private, are such that we cannot infer the safety of any practice followed in the East merely from its long continuance.

Grain, however, may be long kept in the open air in climates much less dry than that of Egypt, without injury, except to the superficial layers; for moisture does not penetrate to a great depth in a heap of grain once well dried and kept well aired. When Louis IX. was making his preparations for his campaign in the East, he had large quantities of wine and grain purchased in the Island of Cyprus, and stored up for two years to await his arrival. "When we were come to Cyprus," says Joinville, *Histoire de Saint Louis*, §§ 72, 73, "we found there greate foison of the Kynge's purveyance. . . The wheate and the barley they had piled up in greate heapes in the feeldes, and to looke vpon, they were like vnto mountaynes; for the raine, the whyche hadde beaten vpon the wheate now a longe whyle, had made it to sproute on the toppe, so that it seemed as greene grasse. And whanne they were mynded to carrie it to Egypte, they brake that sod of greene herbe, and dyd finde under the same the wheate and the barley, as freshe as yf menne hadde but nowe thrashed it."

the present geological period, covered with forests. Besides this, the distribution of forest land, of desert, and of water, is such as to reduce the possible influence of the woods to a low expression; for the forests are, in large proportion, situated in cold or temperate climates, where the action of the sun is comparatively feeble both in elevating temperature and in promoting evaporation; while, in the torrid zone, the desert and the sea—the latter of which always presents an evaporable surface—enormously preponderate. It is, upon the whole, not probable that so small an extent of forest, so situated, could produce a sensible influence on the *general* climate of the globe, though it might appreciably affect the *local* action of all climatic elements. The total annual amount of solar heat absorbed and radiated by the earth, and the sum of terrestrial evaporation and atmospheric precipitation, must be supposed constant; but the distribution of heat and of humidity is exposed to disturbance in both time and place by a multitude of local causes, among which the presence or absence of the forest is doubtless one.

So far as we are able to sum up the results, it would appear that, in countries in the temperate zone still chiefly covered with wood, the summers would be cooler, moister, shorter, the winters milder, drier, longer, than in the same regions after the removal of the forest, and that the condensation and precipitation of atmospheric moisture would be, if not greater in total quantity, more frequent and less violent in discharge. The slender historical evidence we possess seems to point to the same conclusion, though there is some conflict of testimony and of opinion on this point.

Among the many causes which, as we have seen, tend to influence the general result, the mechanical action of the forest, if not more important, is certainly more obvious and direct than the immediate effects of its organic processes. The felling of the woods involves the sacrifice of a valuable protection against the violence of chilling winds and the loss of the shelter afforded to the ground by the thick coating of leaves which the forest sheds upon it and by the snow which the woods prevent from blowing away, or from melting in the brief thaws of winter. I have already remarked that bare ground freezes much deeper than that which is covered by beds of leaves, and when the earth is thickly coated with snow, the strata frozen before it fell begin to thaw. It is not uncommon to find the ground in the woods, where the snow lies two or three feet deep, entirely free from frost, when the atmospheric temperature has been for several weeks below the freezing-point, and for some days even below the zero of Fahrenheit. When the ground is cleared and brought under cultivation, the leaves are ploughed into the soil and decomposed, and the snow, especially upon knolls and eminences, is blown off, or perhaps half thawed, several times during the winter. The water from the melting snow runs into the depressions, and when, after a day or two of warm sunshine or tepid rain, the cold returns, it is consolidated to ice, and the bared ridges and swells of earth are deeply frozen.* It requires many days of mild weather to raise the temperature of soil in this condition, and of the air in contact with it, to that of the earth in the forests of the same climatic region. Flora is already plaiting her sylvan wreath before the corn-flowers which are to deck the garland of Ceres have waked from their winter's sleep; and it is probably not a popular error to believe that, where man has substituted his artificial crops for the spontaneous harvest of nature, spring delays her coming.†

---

* I have seen, in Northern New England, the surface of the open ground frozen to the depth of twenty-two inches, in the month of November, when in the forest-earth no frost was discoverable; and later in the winter, I have known an exposed sand-knoll to remain frozen six feet deep, after the ground in the woods was completely thawed.

† The conclusion arrived at by Noah Webster, in his very learned and able paper on the supposed change in the temperature of winter, read before the Connecticut Academy of Arts and Sciences in 1799, was as follows: "From a careful comparison of these facts, it appears that the weather, in modern winters, in the United States, is more inconstant than when the earth was covered with woods, at the first settlement of Europeans in the country; that the warm weather of autumn extends further into the winter months, and the cold weather of winter and spring encroaches upon the summer; that, the

There are, in the constitution and action of the forest, many forces, organic and inorganic, which unquestionably tend powerfully to produce meteorological effects, and it may, therefore, be assumed as certain that they must and do produce such effects, *unless* they compensate and balance each other, and herein lies the difficulty of solving the question. To some of these elements late observations give a new importance. For example, the exhalation of aqueous vapor by plants is now believed to be much greater, and the absorption of aqueous vapor by them much less, than was formerly supposed, and Tyndall's views on the relations of vapor to atmospheric heat give immense value to this factor in the problem. In like manner the low temperature of the surface of snow and the comparatively high temperature of its lower strata, and its consequent action on the soil beneath, and the great condensation of moisture by snow, are facts which seem to show that the forest, by protecting great surfaces of snow from melting, must inevitably exercise a great climatic influence. If to these influences we add the mechanical action of the woods in obstructing currents of wind, and diminishing the evaporation and refrigeration which such currents produce, we have an accumulation of forces which *must* manifest great climatic effects, unless—which is not proved and cannot be presumed—they neutralize each other. These are points hitherto little considered in the discussion, and it seems difficult to deny that as a question of *argument*, the probabilities are strongly in favor of the meteorological influence of the woods. The *evidence*, indeed, is not satisfactory, or, to speak more accurately, it is non-existent, for there really is next to no trustworthy proof on the subject, but it appears to me a case where the burden of proof must be taken

---

wind being more variable, snow is less permanent, and perhaps the same remark may be applicable to the ice of the rivers. These effects seem to result necessarily from the greater quantity of heat accumulated in the earth in summer since the ground has been cleared of wood and exposed to the rays of the sun, and to the greater depth of frost in the earth in winter by the exposure of its uncovered surface to the cold atmosphere."—*Collection of Papers by* NOAH WEBSTER, p. 162.

by those who maintain that, as a meteorological agent, the forest is inert.

The question of a change in the climate of the Northern American States is examined in the able Meteorological Report of Mr. Draper, Director of the New York Central Park Observatory, for 1871. The result arrived at by Mr. Draper is, that there is no satisfactory evidence of a diminution in the rainfall, or of any other climatic change in the winter season, in consequence of clearing of the forests or other human action. The proof from meteorological registers is certainly insufficient to establish the fact of a change of climate, but, on the other hand, it is equally insufficient to establish the contrary. Meteorological stations are too few, their observations, in many cases, extend over a very short period, and, for reasons I have already given, the great majority of their records are entitled to little or no confidence.*

---

* Since these pages were written, the subject of forest meteorology has received the most important contribution ever made to it, in several series of observations at numerous stations in Bavaria, from the year 1866 to 1871, published by Ebermayer, at Aschaffenburg, in 1873, under the title: *Die Physikalischen Einwirkungen des Waldes auf Luft und Boden, und seine Klimatologische und Hygienische Bedeutung.* I. Band. So far as observations of only five years' duration can prove anything, the following propositions, not to speak of many collateral and subsidiary conclusions, seem to be established, at least for the localities where the observations were made:

1. The yearly mean temperature of wooded *soils*, at all depths, is lower than that of open grounds, p. 35.

This conclusion, it may be remarked, is of doubtful applicability in regions of excessive climate like the Northern United States and Canada, where the snow keeps the temperature of the soil in the forest above the freezing-point, for a large part and sometimes the whole of the winter, while in unwooded ground the earth remains deeply frozen.

2. The yearly mean *atmospheric* temperature, other things being equal, is lower in the forest than in cleared grounds, p. 84.

3. Climates become excessive in consequence of extensive clearings, p. 117.

4. The *absolute* humidity of the air in the forest is about the same as in open ground, while the *relative* humidity is greater in the former than in the latter case, on account of the lower temperature of the atmosphere in the wood, p. 150.

5. The evaporation from an exposed surface of water in the forest is sixty-four per cent. less than in unwooded grounds, pp. 159, 161.

Influence of the Forest on the Humidity of the Soil.

I have hitherto confined myself to the influence of the forest on meteorological conditions, a subject, as has been seen, full of difficulty and uncertainty. Its comparative effects on the temperature, the humidity, the texture and consistence, the configuration and distribution of the mould or arable soil, and, very often, of the mineral strata below, and on the permanence and regularity of springs and greater superficial water-courses, are much less disputable as well as more easily estimated and more important, than its possible value as a cause of strictly climatic equilibrium or disturbance.

The action of the forest on the earth is chiefly mechanical, but the organic process of absorption of moisture by its roots affects the quantity of water contained in the vegetable mould and in the mineral strata near the surface, and, consequently, the consistency of the soil. In treating of the effects of trees on the moisture of the atmosphere, I have said that the forest, by interposing a canopy between the sky and the ground, and by covering the surface with a thick mantle of fallen leaves, at once obstructed insulation and prevented the radiation of heat from the earth. These influences go far to balance each other; but familiar observation shows that, in summer, the forest-soil is not raised to so high a temperature as open grounds exposed to irradiation. For this reason, and in consequence of the mechanical resistance opposed by the bed of dead leaves to the escape of moisture, we should expect that, except after recent rains, the superficial strata of woodland-soil would be more

---

6. About twenty-six per cent. of the precipitation is intercepted and prevented from reaching the ground by the foliage and branches of forest trees, p. 194.

7. In the interior of thick woods, the evaporation from water and from earth is much less than the precipitation, p. 210.

8. The loss of the water of precipitation intercepted by the trees in the forest is compensated by the smaller evaporation from the ground, p. 219.

9. In elevated regions and during the summer half of the year, woods tend to increase the precipitation, p. 202.

humid than that of cleared land. This agrees with experience. The soil of the natural forest is always moist, except in the extremest droughts, and it is exceedingly rare that a primitive wood suffers from want of humidity. How far this accumulation of water affects the condition of neighboring grounds by lateral infiltration, we do not know, but we shall see, in a subsequent chapter, that water is conveyed to great distances by this process, and we may hence infer that the influence in question is an important one.

It is undoubtedly true that loose soils, stripped of vegetation and broken up by the plough or other processes of cultivation, may, until again carpeted by grasses or other plants, absorb more rain and snow-water than when they were covered by a natural growth; but it is also true that the evaporation from such soils is augmented in a still greater proportion. Rain scarcely penetrates beneath the sod of grass-ground, but runs off over the surface; and after the heaviest showers a ploughed field will often be dried by evaporation before the water can be carried off by infiltration, while the soil of a neighboring grove will remain half saturated for weeks together. Sandy soils frequently rest on a tenacious subsoil, at a moderate depth, as is usually seen in the pine plains of the United States, where pools of rain-water collect in slight depressions on the surface of earth the upper stratum of which is as porous as a sponge. In the open grounds such pools are very soon dried up by the sun and wind; in the woods they remain unevaporated long enough for the water to diffuse itself laterally until it finds, in the subsoil, crevices through which it may escape, or slopes which it may follow to their outcrop or descend along them to lower strata.

Drainage by Roots of Trees.

Becquerel notices a special function of the forest to which I have already alluded, but to which sufficient importance has not, until very recently, been generally ascribed. I refer to the mechanical action of the roots as conductors of the superfluous humidity of the superficial earth to lower strata. The roots of trees often penetrate through subsoil almost impervious to water, and in such cases the moisture, which would otherwise remain above the subsoil and convert the surface-earth into a bog, follows the roots downwards and escapes into more porous strata or is received by subterranean canals or reservoirs.* When the forest is felled, the roots perish and decay, the orifices opened by them are soon obstructed, and the water, after having saturated the vegetable earth, stagnates on the surface and transforms it into ponds and morasses. Thus in La Brenne, a tract of 200,000 acres resting on an impermeable subsoil of argillaceous earth, which ten centuries ago was covered with forests interspersed with fertile and salubrious meadows and pastures, has been converted, by the destruction of the woods, into a vast expanse of pestilential pools and marshes. In Sologne the same cause has withdrawn from cultivation and human inhabitation not less than 1,100,000 acres of ground once well wooded, well drained, and productive.

It is an important observation that the desiccating action of trees, by way of drainage or external conduction by the roots, is greater in the artificial than in the natural wood, and hence that the surface of the ground in the former is not characterized by that approach to a state of saturation which it so generally manifests in the latter. In the spontaneous wood, the leaves, fruits, bark, branches, and dead trunks, by their decayed material and by the conversion of rock into loose earth through the solvent power of the gases they develop in decomposition, cover the ground with an easily penetrable stratum of mixed vegetable and mineral matter extremely favorable to the growth of trees, and at the same time too retentive of moisture to part with it readily to the capillary attraction of the roots. The trees, finding abundant nutriment near the surface, and so sheltered against the action of the wind by each other as not to need the support of deep and firmly fixed stays, send their roots but a moderate distance downwards, and indeed often spread them out like a horizontal network almost on the surface of the ground. In the artificial wood, on the contrary, the spaces between the trees are greater; they are obliged to send their roots deeper both for mechanical support and in search of nutriment, and they consequently serve much more effectually as conduits for perpendicular drainage.

---

* "The roots of vegetables," says d'Héricourt, "perform the office of draining in a manner analogous to that artificially practised in parts of Holland and the British islands. This method consists in driving deeply down into the soil several hundred stakes to the acre; the water filters down along the stakes, and in some cases as favorable results have been obtained by this means as by horizontal drains."—*Annales Forestières*, 1857, p. 312.

It is only under special circumstances, however, that this function of the forest is so essential a conservative agent as in the two cases just cited. In a champaign region insufficiently provided with natural channels for the discharge of the waters, and with a subsoil which, though penetrable by the roots of trees, is otherwise impervious to water, it is of cardinal importance; but though trees everywhere tend to carry off the moisture of the superficial strata by this mode of conduction, yet the precise condition of soil which I have described is not of sufficiently frequent occurrence to have drawn much attention to this office of the wood. In fact, in most soils, there are counteracting influences which neutralize, more or less effectually, the desiccative action of roots, and in general it is as true as it was in Seneca's time, that "the shadiest grounds are the moistest." *

It is always observed in the American States, that clearing the ground not only causes running springs to disappear, but dries up the stagnant pools and the spongy soils of the low grounds. The first roads in those States ran along the ridges, when practicable, because there only was the earth dry enough to allow of their construction, and, for the same reason, the cabins of the first settlers were perched upon the hills. As the forests have been from time to time removed, and the face of

---

* SENECA, *Questiones Naturales*, iii. 11, 2.

the earth laid open to the air and sun, the moisture has been evaporated, and the removal of the highways and of human habitations from the bleak hills to the sheltered valleys, is one of the most agreeable among the many improvements which later generations have witnessed in the interior of the Northern States.*

Recent observers in France affirm that evergreen trees exercise a special desiccating action on the soil, and cases are cited where large tracts of land lately planted with pines have been almost completely drained of moisture by some unknown action of the trees. It is argued that the alleged drainage is not due to the conducting power of the roots, inasmuch as the roots of the pine do not descend lower than those of the oak and other deciduous trees which produce no such effect, and it is suggested that the foliage of the pine continues to exhale through the winter a sufficient quantity of moisture to account for the drying up of the soil. This explanation is improbable, and I know nothing in American experience of the forest which accords with the alleged facts. It is true that the pines, the firs, the hemlock, and all the spike-leaved evergreens prefer a dry soil, but it has not been observed that such soils become less dry after the felling of their trees. The cedars and other trees of allied families grow naturally in moist ground, and the white cedar of the Northern States, *Thuya occidentalis*, is chiefly found in swamps. The roots of this tree do not penetrate deeply into the earth, but are spread out near the surface, and of course do not carry off the waters of the swamp by perpendicular conduction. On the contrary, by their shade, the trees prevent the evaporation of the superficial water; but when the cedars are felled, the swamp—which sometimes rather resembles a pool filled with aquatic trees than a grove upon solid ground—often dries up so completely as to be fit for cultivation without any other artificial drainage than, in the ordinary course of cultivation, is given to other new soils.*

---

* The Tuscan poet Giusti, who had certainly had little opportunity of observing primitive conditions of nature and of man, was aware that such must have been the course of things in new countries. "You know," says he in a letter to a friend, "that the hills were first occupied by man, because stagnant waters, and afterwards continual wars, excluded men from the plains. But when tranquillity was established and means provided for the discharge of the waters, the low grounds were soon covered with human habitations."—*Lettere*, Firenze, 1864, p. 98.

The Forest in Winter.

The influence of the woods on the flow of springs, and consequently on the supply for the larger water-courses, naturally connects itself with the general question of the action of the forest on the humidity of the ground. But the special condition of the woodlands, as affected by snow and frost in the winter of excessive climates, like that of the United States, has not been so much studied as it deserves; and as it has a most important bearing on the superficial hydrology of the earth, I shall make some observations upon it before I proceed to the direct discussion of the influence of the forest on the flow of springs.

To estimate rightly the importance of the forest in our climate as a natural apparatus for accumulating the water that falls upon the surface and transmitting it to the subjacent strata, we must compare the condition and properties of its soil with those of cleared and cultivated earth, and examine the consequently different action of these soils at different seasons of the year. The disparity between them is greatest in climates where, as in the Northern American States and in the extreme North of Europe, the open ground freezes and remains impervious to water during a considerable part of the winter; though, even in climates where the earth does not freeze at all, the woods have still an important influence of the same character. The difference is yet greater in countries which have regular wet and dry seasons, rain being very frequent in the former period, while, in the latter, it scarcely occurs at all. These countries lie chiefly in or near the tropics, but they are not wanting in higher latitudes; for a large part of Asiatic and even of European Turkey is almost wholly deprived of summer rains. In the principal regions occupied by European cultivation, and where alone the questions discussed in this volume are recognized as having, at present, any practical importance, more or less rain falls at all seasons, and it is to these regions that, on this point as well as others, I chiefly confine my attention.

---

* A special desiccative influence has long been ascribed to the maritime pine, which has been extensively planted on the dunes and sand-plains of western France, and it is well established that, under certain conditions, all trees, whether evergreen or deciduous, exercise this function, but there is no convincing proof that in the cases now referred to there is any difference in the mode of action of the two classes of trees. An article by D'Arbois de Jubainville in the *Revue des Eaux et Forêts* for April, 1869, ascribing the same action to the *Pinus sylvestris*, has excited much attention in Europe, and the facts stated by this writer constitute the strongest evidence known to me in support of the alleged influence of evergreen trees, as distinguished from the draining by downward conduction, which is a function exercised by all trees, under ordinary circumstances, in proportion to their penetration of a bibulous subsoil by tap or other descending roots. The question has been ably discussed by Béraud in the *Revue des Deux Mondes* for April, 1870, the result being that the drying of the soil by pines is due simply to conduction by the roots, whatever may be the foliage of the tree. See *post: Influence of the Forest on Flow of Springs.*

It is however certain, I believe, that evergreens exhale more moisture in winter than leafless deciduous trees, and consequently some weight is to be ascribed to this element.

Importance of Snow.

Recent observations in Switzerland give a new importance to the hygrometrical functions of snow, and of course to the forest as its accumulator and protector. I refer to statements of the condensation of atmospheric vapor by the snows and glaciers of the Rhone basin, where it is estimated to be nearly equal to the entire precipitation of the valley. Whenever the humidity of the atmosphere in contact with snow is above the point of saturation at the temperature to which the air is cooled by such contact, the superfluous moisture is absorbed by the snow or condensed and frozen upon its surface, and of course adds so much to the winter supply of water received from the snow by the ground. This quantity, in all probability, much exceeds the loss by evaporation, for during the period when the ground is covered with snow, the proportion of clear dry weather favorable to evaporation is less than that of humid days with an atmosphere in a condition to yield up its moisture to any bibulous substance cold enough to condense it.*

In our Northern States, irregular as is the climate, the first autumnal snows pretty constantly fall before the ground is frozen at all, or when the frost extends at most to the depth of only a few inches.† In the woods, especially those situated upon the elevated ridges which supply the natural irrigation of the soil and feed the perennial fountains and streams, the ground remains covered with snow during the winter; for the trees protect the snow from blowing from the general surface into the depressions, and new accessions are received before the covering deposited by the first fall is melted. Snow is of a color unfavorable for radiation, but, even when it is of considerable thickness, it is not wholly impervious to the rays of the sun, and for this reason, as well as from the warmth of lower strata, the frozen crust of the soil, if one has been formed, is soon thawed, and does not again fall below the freezing-point during the winter.‡

---

* The hard snow-crust, which in the early spring is a source of such keen enjoyment to the children and youth of the North—and to many older persons in whom the love of nature has kept awake a relish for the simple pleasures of rural life—is doubtless due to the congelation of the vapor condensed by the snow rather than to the thawing and freezing of the superficial stratum; for when the surface is melted by the sun, the water is taken up by the absorbent mass beneath before the temperature falls low enough to freeze it.

† The hard autumnal frosts are usually preceded by heavy rains which thoroughly moisten the soil, and it is a common saying in the North that "the ground will not freeze till the swamps are full."

‡ Dr. Williams, of Vermont, made some observations on the comparative temperature of the soil in open and in wooded ground in the years 1789 and 1791, but they generally belonged to the warmer months, and I do not know that any extensive series of comparisons between the temperature of the ground in the woods and in the fields has been attempted in America. Dr.

The snow in contact with the earth now begins to melt, with greater or less rapidity, according to the relative temperature of the earth and the air, while the water resulting from its dissolution is imbibed by the vegetable mould, and carried off by infiltration so fast that both the snow and the layers of leaves in contact with it often seem comparatively dry, when, in fact, the under-surface of the former is in a state of perpetual thaw. No doubt a certain proportion of the snow is given off to the atmosphere by direct evaporation, but in the woods, the protection against the sun by even leafless trees prevents much loss in this way, and besides, the snow receives much moisture from the air by absorption and condensation. Very little

---

Williams's thermometer was sunk to the depth of ten inches, and gave the following results:

TIME.	Temperature of ground in pasture.	Temperature of ground in woods.	Difference.
May 23	52	46	6
" 28	57	48	9
June 15	64	51	13
" 27	62	51	11
July 16	62	51	11
" 30	65½	55½	10
Aug. 15	68	58	10
" 31	59½	55	4½
Sept. 15	59½	55	4½
Oct. 1	59½	55	4½
" 15	49	49	0
Nov. 1	43	43	0
" 16	43½	43½	0

On the 14th of January, 1791, in a winter remarkable for its extreme severity, he found the ground, on a plain open field where the snow had been blown away, frozen to the depth of three feet and five inches; in the woods where the snow was three feet deep, and where the soil had frozen to the depth of six inches before the snow fell, the thermometer, at six inches below the surface of the ground, stood at 39°. In consequence of the covering of the snow, therefore, the previously frozen ground had been thawed and raised to seven degrees above the freezing-point.—WILLIAMS's *Vermont*, i., p. 74.

Boussingault's observations are important. Employing three thermometers, water runs off in the winter by superficial water-courses, except in rare cases of sudden thaw, and there can be no question that much the greater part of the snow deposited in the forest is slowly melted and absorbed by the earth.

The immense importance of the forest, as a reservoir of this stock of moisture, becomes apparent, when we consider that a large proportion of the summer rain either flows into the valleys and the rivers, because it falls faster than the ground can imbibe it; or, if absorbed by the warm superficial strata, is evaporated from them without sinking deep enough to reach wells and springs, which, of course, depend much on winter rains and snows for their entire supply. This observation, though specially true of cleared and cultivated grounds, is not wholly inapplicable to the forest, particularly when, as is too often the case in Europe, the underwood and the decaying leaves are removed.

---

one with the bulb an inch below the surface of powdery snow; one on the surface of the ground beneath the snow, then four inches deep; and one in the open air, forty feet above the ground, on the north side of a building, he found, at 5 P.M., the *first* thermometer at —1.5° Centigrade, the *second* at 0°, and the *third* at +2.5°; at 7 A.M. the next morning, the first stood at —12°, the second at —3.5°, and the third at —3°; at 5.30 the same evening No. 1 stood at —1.4°, No. 2 at 0°, and No. 3 at + 3°. Other experiments were tried, and though the temperature was affected by the radiation, which varied with the hour of the day and the state of the sky, the upper surface of the snow was uniformly colder than the lower, or than the open air.

According to the Report of the Department of Agriculture for May and June, 1872, Mr. C. G. Prindle, of Vermont, in the preceding winter, found, for four successive days, the temperature immediately above the snow at 13° below zero; beneath the snow, which was but four inches deep, at 19° above zero; and under a drift two feet deep, at 27° above.

On the borders and in the glades of the American forest, violets and other small plants begin to vegetate as soon as the snow has thawed the soil around their roots, and they are not unfrequently found in full flower under two or three feet of snow.—*American Naturalist*, May, 1869, pp. 155, 156.

In very cold weather, when the ground is covered with light snow, flocks of the grouse of the Eastern States often plunge into the snow about sunset, and pass the night in this warm shelter. If the weather moderates before morning, a frozen crust is sometimes formed on the surface too strong to be broken by the birds, which consequently perish.

The quantity of snow that falls in extensive forests, far from the open country, has seldom been ascertained by direct observation, because there are few meteorological stations in or near the forest. According to Thompson,* the proportion of water which falls in snow in the Northern States does not exceed one-fifth of the total precipitation, but the moisture derived from it is doubtless considerably increased by the atmospheric vapor absorbed by it, or condensed and frozen on its surface. I think I can say from experience—and I am confirmed in this opinion by the testimony of competent observers whose attention has been directed specially to the point—that though much snow is intercepted by the trees, and the quantity on the ground in the woods is consequently less than in open land in the first part of the winter, yet most of what reaches the ground at that season remains under the protection of the wood until melted, and as it occasionally receives new supplies the depth of snow in the forest in the latter half of winter is considerably greater than in the cleared fields. Careful measurements in a snowy region in New England, in the month of February, gave a mean of 38 inches in the open ground and 44 inches in the woods.†

The general effect of the forest in cold climates is to assim-

---

* THOMPSON'S *Vermont*, Appendix, p. 8.

† As the loss of snow by evaporation has been probably exaggerated by popular opinion, an observation or two on the subject may not be amiss in this place. It is true that in the open grounds, in clear weather and with a dry atmosphere, snow and ice are evaporated with great rapidity even when the thermometer is much below the freezing-point; and Darwin informs us that the snow on the summit of Aconcagua, 23,000 feet high, and of course in a temperature of perpetual frost, is sometimes carried off by evaporation. The surface of the snow in our woods, however, does not indicate much loss in this way. Very small deposits of snow-flakes remain unevaporated in the forest, for many days after snow which fell at the same time in the cleared field has disappeared without either a thaw to melt it or a wind powerful enough to drift it away. Even when bared of their leaves, the trees of a wood obstruct, in an important degree, both the direct action of the sun's rays on the snow and the movement of drying and thawing winds.

Dr. Piper (*Trees of America*, p. 48) records the following observations: "A body of snow, one foot in depth and sixteen feet square, was protected from ilate the winter state of the ground to that of wooded regions under softer skies; and it is a circumstance well worth noting, that in Southern Europe, where Nature has denied to the earth a warm winter-garment of flocculent snow, she has, by one of those compensations in which her empire is so rich, clothed the hillsides with umbrella and other pines, ilexes, cork-oaks, bays, and other trees of persistent foliage, whose evergreen leaves afford to the soil a protection analogous to that which it derives from snow in more northern climates.

The water imbibed by the soil in winter sinks until it meets a more or less impermeable or a saturated stratum, and then, by unseen conduits, slowly finds its way to the channels of springs, or oozes out of the ground in drops which unite in rills, and so all is conveyed to the larger streams, and by them finally to the sea. The water, in percolating through the vegetable and mineral layers, acquires their temperature, and is chemically affected by their action, but it carries very little matter in mechanical suspension.

The process I have described is a slow one, and the supply of moisture derived from the snow, augmented by the rains of the following seasons, keeps the forest-ground, where the surface is level or but moderately inclined, in a state of approximate saturation throughout almost the whole year. *

---

the wind by a tight board fence about five feet high, while another body of snow, much more sheltered from the sun than the first, six feet in depth, and about sixteen feet square, was fully exposed to the wind. When the thaw came on, which lasted about a fortnight, the larger body of snow was entirely dissolved in less than a week, while the smaller body was not wholly gone at the end of the second week.

"Equal quantities of snow were placed in vessels of the same kind and capacity, the temperature of the air being seventy degrees. In the one case, a constant current of air was kept passing over the open vessel, while the other was proteectd by a cover. The snow in the first was dissolved in sixteen minutes, while the latter had a small unthawed proportion remaining at the end of eighty-five minutes."

The snow in the woods is protected in the same way, though not literally to the same extent, as by the fence in one of these cases and the cover in the other.

* The statements I have made, here and elsewhere, respecting the humidity

It may be proper to observe here that in Italy, and in many parts of Spain and France, the Alps, the Apennines, and the Pyrenees, not to speak of less important mountains, perform the functions which provident nature has in other regions assigned to the forest, that is, they act as reservoirs wherein is accumulated in winter a supply of moisture to nourish the parched plains during the droughts of summer. Hence, however enormous may be the evils which have accrued to the above-mentioned countries from the destruction of the woods, the absolute desolation which would otherwise have smitten them through the folly of man, has been partially prevented by those natural dispositions, by means of which there are stored up in the glaciers, in the snow-fields, and in the basins of mountains and valleys, vast deposits of condensed moisture which are afterwards distributed in a liquid form during the season in which the atmosphere furnishes a slender supply of the beneficent fluid so indispensable to vegetable and animal life.*

Summer Rains, Importance of.

Babinet quotes a French proverb: "Summer rain wets nothing," and explains it by saying that at that season the rain-

---

of the soil in natural forests, have been, I understand, denied by Mr. T. Meehan, a distinguished American naturalist, in a paper which I have not seen. He is quoted as maintaining, among other highly questionable propositions, that no ground is "so dry in its subsoil as that which sustains a forest on its surface." In open, artificially planted woods, with a smooth and regular surface, and especially in forests where the fallen leaves and branches are annually burnt or carried off, both the superficial and the subjacent strata may, under certain circumstances, become dry, but this rarely, if ever, happens in a wood of spontaneous growth, undeprived of the protection afforded by its own droppings, and of the natural accidents of surface which tend to the retention of water. See, on this point, a very able article by Mr. Henry Stewart, in the New York *Tribune* of November 25, 1873.

* The accumulation of snow and ice upon the Alps and other mountains—which often fills up valleys to the height of hundreds of feet—is due not only to the fall of congealed and crystallized vapor in the form of snow, to the condensation of atmospheric vapor on the surface of snow-fields and glaciers, and to a temperature which prevents the rapid melting of snow, but also to

water is "almost entirely carried off by evaporation." "The rains of summer," he adds, "however abundant they may be, do not penetrate the soil beyond the depth of six or eight inches. In summer the evaporating power of the heat is five or six times greater than in winter, and this force is exerted by an atmosphere capable of containing five or six times as much vapor as in winter." "A stratum of snow which prevents evaporation [from the ground], causes almost all the water that composes it to filter into the earth, and forms a provision for fountains, wells, and streams which could not be furnished by any quantity whatever of summer rain. This latter, useful to vegetation like the dew, neither penetrates the soil nor accumulates a store to supply the springs and to be given out again into the open air." [*]

---

the well-known fact that, at least up to the height of 10,000 feet, rain and snow are more abundant on the mountains than at lower levels.

But another reason may be suggested for the increase of atmospheric humidity, and consequently of the precipitation of aqueous vapor on mountain chains. In discussing the influence of mountains on precipitation, meteorologists have generally treated the popular belief, that mountains "attract" to them clouds floating within a certain distance from them, as an ignorant prejudice, and they ascribe the appearance of clouds about high peaks solely to the condensation of the humidity of the air carried by atmospheric currents up the slopes of the mountain to a colder temperature. But if mountains do not really draw clouds and invisible vapors to them, they are an exception to the universal law of attraction. The attraction of the small Mount Sheballien was found sufficient to deflect from the perpendicular, by a measurable quantity, a plummet weighing but a few ounces. Why, then, should not greater masses attract to them volumes of vapor weighing many tons, and floating freely in the atmosphere within moderate distances of the mountains?

[*] *Études et Lectures*, vol. vi., p. 118. The experiments of Johnstrup in the vicinity of Copenhagen, where the mean annual precipitation is 23½ inches, and where the evaporation must be less than in the warmer and drier atmosphere of France, form the most careful series of observations on this subject which I have met with. Johnstrup found that at the depth of a metre and a half (59 inches) the effects of rain and evaporation were almost imperceptible, and became completely so at a depth of from two to three metres (6½ to 10 feet). During the summer half of the year the evaporation rather exceeded the rainfall; during the winter half the entire precipitation was absorbed by the soil and transmitted to lower strata by infiltration. The

This conclusion, however applicable to the climate and to the soil of France, is too broadly stated to be received as a general truth; and in countries like the United States, where rain is comparatively rare during the winter and abundant during the summer half of the year, common observation shows that the quantity of water furnished by deep wells and by natural springs depends almost as much upon the rains of summer as upon those of the rest of the year, and consequently that a large portion of the rain of that season must find its way into strata too deep for the water to be wasted by evaporation.*

---

stratum between one metre and a half (59 inches) and three metres (10 feet) from the surface was then permanently in the condition of a saturated sponge, neither receiving nor losing humidity during the summer half of the year, but receiving from superior, and giving off to lower, strata an equal amount of moisture during the winter half.—JOHNSTRUP, *Om Fugtighedens Bevægelse i den naturlige Jordbund.* Kjöbenhavn, 1866.

Dalton's experiments in the years 1796, 1797, and 1798 appeared to show that the mean absorption of the downfall by the earth in those years was twenty-nine per cent.

Dickinson, employing the same apparatus for eight years, found the absorption to vary widely in different years, the mean being forty-seven per cent.

Charnock's experiments in two years show an absorption of from seventeen to twenty-seven per cent.

* According to observations at one hundred military stations in the United States, the precipitation ranges from three and a quarter inches at Fort Yuma in California to about seventy-two inches at Fort Pike, Louisiana, the mean for the entire territory, not including Aliaska, being thirty-six inches. In the different sections of the Union it is as follows:

North-eastern States	41	inches.
New York	36	"
Middle States	40½	"
Ohio	40	"
Southern States	51	"
S. W. States and Indian Territories	39½	"
Western States and Territories	30	"
Texas and New Mexico	24½	"
California	18½	"
Oregon and Washington Territory	50	"

The mountainous regions, it appears, do not receive the greatest amount of precipitation. The average downfall of the Southern States bordering on the

Besides, even admitting that the water from summer rains is so completely evaporated as to contribute nothing directly to the supply of springs, it at least tends indirectly to maintain their flow, because it saturates in part the atmosphere, and at the same time it prevents the heat of the sun from drying the earth to still greater depths, and bringing within the reach of evaporation the moisture of strata which ordinarily do not feel the effects of solar irradiation.

Influence of the Forest on the Flow of Springs.

It is an almost universal and, I believe, well-founded opinion, that the protection afforded by the forest against the escape of moisture from its soil by superficial flow and evaporation insures the permanence and regularity of natural springs, not only within the limits of the wood, but at some distance beyond its borders, and thus contributes to the supply of an element essential to both vegetable and animal life. As the forests are destroyed, the springs which flowed from the woods, and, consequently, the greater water-courses fed by them, diminish both in number and in volume. This fact is so familiar throughout the American States and the British Provinces, that there are few old residents of the interior of those districts who are not able to testify to its truth as a matter of personal observation. My own recollection suggests to me many instances of this sort, and I remember one case where a small mountain spring, which disappeared soon after the clearing of the ground where it rose, was recovered about twenty years ago, by simply allowing the bushes and young trees to grow up on a rocky knoll, not more

---

Atlantic and the Gulf of Mexico exceeds the mean of the whole United States, being no less than fifty-one inches, while on the Pacific coast it ranges from fifty to fifty-six inches.

As a general rule, it may be stated that at the stations on or near the seacoast the precipitation is greatest in the spring months, though there are several exceptions to this remark, and at a large majority of the stations the downfall is considerably greater in the summer months than at any other season.

than half an acre in extent, immediately above the spring. The ground was hardly shaded before the water reappeared, and it has ever since continued to flow without interruption. The hills in the Atlantic States formerly abounded in springs and brooks, but in many parts of these States which were cleared a generation or two ago, the hill-pastures now suffer severely from drought, and in dry seasons furnish to cattle neither grass nor water.

Almost every treatise on the economy of the forest adduces facts in support of the doctrine that the clearing of the woods tends to diminish the flow of springs and the humidity of the soil, and it might seem unnecessary to bring forward further evidence on this point.* But the subject is of too much practical importance and of too great philosophical interest to be summarily disposed of; and it ought to be noticed that there is at least one case—that of some loose sandy soils which, as observed by Vallès,† when bared of wood very rapidly absorb and transmit to lower strata the water they receive from the atmosphere—where the removal of the forest may increase the flow of springs at levels below it, by exposing to the rain and melted snow a surface more bibulous, and at the same time less retentive, than its original covering. Under such circumstances, the water of precipitation, which had formerly been absorbed by the vegetable mould and retained until it was evaporated, might descend through porous earth until it meets an impermeable stratum, and then be conducted along it, until, finally, at the outcropping of this stratum, it bursts from a hillside as a running spring. But such instances are doubtless too rare to form a frequent or an important exception to the general law, because it is very seldom the case that such a soil as has just been supposed is covered by a layer of vegetable earth thick enough to retain, until it is evaporated, all the rain that falls upon it, without imparting any water to the strata below it.

---

* "Why go so far for the proof of a phenomenon that is repeated every day under our own eyes, and of which every Parisian may convince himself, without venturing beyond the Bois de Boulogne or the forest of Meudon? Let him, after a few rainy days, pass along the Chevreuse road, which is bordered on the right by the wood, on the left by cultivated fields. The fall of water and the continuance of the rain have been the same on both sides; but the ditch on the side of the forest will remain filled with water proceeding from the infiltration through the wooded soil, long after the other, contiguous to the open ground, has performed its office of drainage and become dry. The ditch on the left will have discharged in a few hours a quantity of water, which the ditch on the right requires several days to receive and carry down to the valley."—CLAVÉ, *Études*, etc., pp. 53, 54.

† VALLÈS, *Études sur les Inondations*, p. 472.

If we look at the point under discussion as purely a question of fact, to be determined by positive evidence and not by argument, the observations of Boussingault are, both in the circumstances they detail and in the weight to be attached to the testimony, among the most important yet recorded. The interest of the question will justify me in giving, nearly in Boussingault's own words, the facts and some of the remarks with which he accompanies the detail of them. "In many localities," he observes,* "it has been thought that, within a certain number of years, a sensible diminution has been perceived in the volume of water of streams utilized as a motive-power; at other points, there are grounds for believing that rivers have become shallower, and the increasing breadth of the belt of pebbles along their banks seems to prove the loss of a part of their water; and, finally, abundant springs have almost dried up. These observations have been principally made in valleys bounded by high mountains, and it has been noticed that this diminution of the waters has immediately followed the epoch when the inhabitants have begun to destroy, unsparingly, the woods which were spread over the face of the land.

"And here lies the practical point of the question; for if it is once established that clearing diminishes the volume of streams, it is less important to know to what special cause this effect is due. The rivers which rise within the valley of Aragua, having no outlet to the ocean, form, by their union, the Lake of Tacarigua or Valencia, having a length of about two leagues and a half [= 7 English miles].

---

* *Économie Rurale*, t. ii., p. 730.

"At the time of Humboldt's visit to the valley of Aragua, the inhabitants were struck by the gradual diminution which the lake had been undergoing for thirty years. In fact, by comparing the descriptions given by historians with its actual condition, even making large allowance for exaggeration, it was easy to see that the level was considerably depressed. The facts spoke for themselves. Oviedo, who, toward the close of the sixteenth century, had often traversed the valley of Aragua, says positively that New Valencia was founded, in 1555, at half a league from the Lake of Tacarigua; in 1800, Humboldt found this city 5,260 mètres [= 3½ English miles] from the shore.

"The aspect of the soil furnished new proofs. Many hillocks on the plain retain the name of islands, which they more justly bore when they were surrounded by water. The ground laid bare by the retreat of the lake was converted into admirable plantations; and buildings erected near the lake showed the sinking of the water from year to year. In 1796, new islands made their appearance. A fortress built in 1740 on the island of Cabrera, was now on a peninsula; and, finally, on two granitic islands, those of Cura and Cabo Blanco, Humboldt observed among the shrubs, some mètres above the water, fine sand filled with helicites.

"These clear and positive facts suggested numerous explanations, all assuming a subterranean outlet, which permitted the discharge of the water to the ocean. Humboldt disposed of these hypotheses, and did not hesitate to ascribe the diminution of the waters of the lake to the numerous clearings which had been made in the valley of Aragua within half a century."

Twenty-two years later, Boussingault explored the valley of Aragua. For some years previous, the inhabitants had observed that the waters of the lake were no longer retiring, but, on the contrary, were sensibly rising. Grounds, not long before occupied by plantations, were submerged. The islands of Nuevas Aparecidas, which appeared above the surface in

1796, had again become shoals dangerous to navigation. Cabrera, a tongue of land on the north side of the valley, was so narrow that the least rise of the water completely inundated it. A protracted north wind sufficed to flood the road between Maracay and New Valencia. The fears which the inhabitants of the shores had so long entertained were reversed. Those who had explained the diminution of the lake by the supposition of subterranean channels were suspected of blocking them up, to prove themselves in the right.

During the twenty-two years which had elapsed, the valley of Aragua had been the theatre of bloody struggles, and war had desolated these smiling lands and decimated their population. At the first cry of independence a great number of slaves found their liberty by enlisting under the banners of the new republic; the great plantations were abandoned, and the forest, which in the tropics so rapidly encroaches, had soon recovered a large proportion of the soil which man had wrested from it by more than a century of constant and painful labor.

Boussingault proceeds to state that two lakes near Ubate, in New Granada, had formed but one, a century before his visit; that the waters were gradually retiring, and the plantations extending over the abandoned bed; that, by inquiry of old hunters and by examination of parish records, he found that extensive clearings had been made and were still going on.

He found, also, that the length of the Lake of Fuquené, in the same valley, had, within two centuries, been reduced from ten leagues to one and a half, its breadth from three leagues to one. At the former period, the neighboring mountains were well wooded, but at the time of his visit the mountains had been almost entirely stripped of their wood. Our author adds that other cases, similar to those already detailed, might be cited, and he proceeds to show, by several examples, that the waters of other lakes in the same regions, where the valleys had always been bare of wood, or where the forests had not been disturbed, had undergone no change of level.

Boussingault further states that the lakes of Switzerland have sustained a depression of level since the too prevalent destruction of the woods, and arrives at the general conclusion that, "in countries where great clearings have been made, there has most probably been a diminution in the living waters which flow upon the surface of the ground." This conclusion he further supports by two examples: one, where a fine spring, at the foot of a wooded mountain in the Island of Ascension, dried up when the mountain was cleared, but reappeared when the wood was replanted; the other at Marmato, in the province of Popayan, where the streams employed to drive machinery were much diminished in volume, within two years after the clearing of the heights from which they derived their supplies. This latter is an interesting case, because, although the rain-gauges, established as soon as the decrease of water began to excite alarm, showed a greater fall of rain for the second year of observation than the first, yet there was no appreciable increase in the flow of the mill-streams. From these cases, the distinguished physicist infers that very restricted local clearings may diminish and even suppress springs and brooks, without any reduction in the total quantity of rain.

It will have been noticed that these observations, with the exception of the last two cases, do not bear directly upon the question of the diminution of springs by clearings, but they logically infer it from the subsidence of the natural reservoirs which springs once filled. There is, however, no want of positive evidence on this subject.

Marchand cites the following instances: "Before the felling of the woods, within the last few years, in the valley of the Soulce, the Combe-ès-Mounin and the Little Valley, the Sorne furnished a regular and sufficient supply of water for the iron-works of Unterwyl, which was almost unaffected by drought or by heavy rains. The Sorne has now become a torrent, every shower occasions a flood, and after a few days of fine weather, the current falls so low that it has been necessary to change the water-wheels, because those of the old construction are no longer able to drive the machinery, and at last to introduce a steam-engine to prevent the stoppage of the works for want of water.

"When the factory of St. Ursanne was established, the river that furnished its power was abundant, and had, from time immemorial, sufficed for the machinery of a previous factory. Afterwards, the woods near its sources were cut. The supply of water fell off in consequence, the factory wanted water for half the year, and was at last obliged to stop altogether.

"The spring of Combefoulat, in the commune of Seleate, was well known as one of the best in the country; it was remarkably abundant, and sufficient, in the severest droughts, to supply all the fountains of the town; but as soon as considerable forests were felled in Combe-de-pré Martin and in the valley of Combefoulat, the famous spring, which lies below these woods, has become a mere thread of water, and disappears altogether in times of drought.

"The spring of Varieux, which formerly supplied the castle of Pruntrut, lost more than half its water after the clearing of Varieux and Rougeoles. These woods have been replanted, the young trees are growing well, and, with the woods, the waters of the spring are increasing.

"The Dog Spring between Pruntrut and Bressancourt has entirely vanished since the surrounding forest-grounds were brought under cultivation.

"The Wolf Spring, in the commune of Soubey, furnishes a remarkable example of the influence of the woods upon fountains. A few years ago this spring did not exist. At the place where it now rises, a small thread of water was observed after very long rains, but the stream disappeared with the rain. The spot is in the middle of a very steep pasture inclining to the south. Eighty years ago, the owner of the land, perceiving that young firs were shooting up in the upper part of it, determined to let them grow, and they soon formed a flourishing grove. As soon as they were well grown, a fine spring appeared in place of the occasional rill, and furnished abundant water in the longest droughts. For forty or fifty years this spring was considered the best in the Clos du Doubs. A few years since, the grove was felled, and the ground turned again to a pasture. The spring disappeared with the wood, and is now as dry as it was ninety years ago." *

Siemoni gives the following remarkable facts from his own personal observation:

"In a rocky nook near the crest of a mountain in the Tuscan Apennines, there flowed a clear, cool, and perennial fountain, uniting three distinct springs in a single current. The ancient beeches around and particularly above the springs were felled. On the disappearance of the wood, the springs ceased to flow, except in a thread of water in rainy weather, greatly inferior in quality to that of the old fountain. The beeches were succeeded by firs, and as soon as they had grown sufficiently to shade the soil, the springs began again to flow, and they gradually returned to their former abundance and quality.†

This and the next preceding case are of great importance both as to the action of the wood in maintaining springs, and particularly as tending to prove that evergreens do not exercise the desiccative influence ascribed to them in France. The latter instance shows, too, that the protective influence of the wood extends far below the surface, for the quality of the water was determined, no doubt, by the depth from which it was drawn. The slender occasional supply after the beeches were cut was rain-water which soaked through the superficial humus and oozed out at the old orifices, carrying the taste and temperature of the vegetable soil with it; the more abundant and grateful water which flowed before the beeches were cut, and after the firs were well grown, came from a deeper source and had been purified, and cooled to the mean temperature of the locality, by filtering through strata of mineral earth.

---

* *Ueber die Entwaldung der Gebirge*, pp. 20 *et seqq.*

† *Manuale d'Arte Forestale.* 2da edizione, p. 492.

"The influence of the forest on springs," says Hummel, "is strikingly shown by an instance at Heilbronn. The woods on the hills surrounding the town are cut in regular succession every twentieth year. As the annual cuttings approach a certain point, the springs yield less water, some of them none at all; but as the young growth shoots up, they flow more and more freely, and at length bubble up again in all their original abundance." *

Dr. Piper states the following case: "Within about half a mile of my residence there is a pond upon which mills have been standing for a long time, dating back, I believe, to the first settlement of the town. These have been kept in constant operation until within some twenty or thirty years, when the supply of water began to fail. The pond owes its existence to a stream that has its source in the hills which stretch some miles to the south. Within the time mentioned, these hills, which were clothed with a dense forest, have been almost entirely stripped of trees; and to the wonder and loss of the mill-owners, the water in the pond has failed, except in the season of freshets; and, what was never heard of before, the stream itself has been entirely dry. Within the last ten years a new growth of wood has sprung up on most of the land formerly occupied by the old forest; and now the water runs through the year, notwithstanding the great droughts of the last few years, going back from 1856."

Dr. Piper quotes from a letter of William C. Bryant the following remarks: "It is a common observation that our summers are becoming drier and our streams smaller. Take the Cuyahoga as an illustration. Fifty years ago large barges loaded with goods went up and down that river, and one of the vessels engaged in the battle of Lake Erie, in which the gallant Perry was victorious, was built at Old Portage, six miles north of Albion, and floated down to the lake. Now, in an ordinary stage of the water, a canoe or skiff can hardly pass down the stream. Many a boat of fifty tons burden has been built and

---

* *Physische Geographie*, p. 32.

loaded in the Tuscarawas, at New Portage, and sailed to New Orleans without breaking bulk. Now, the river hardly affords a supply of water at New Portage for the canal. The same may be said of other streams—they are drying up. And from the same cause—the destruction of our forests—our summers are growing drier and our winters colder." *

No observer has more carefully studied the influence of the forest upon the flow of the waters, or reasoned more ably on the ascertained phenomena, than Cantegril. The facts presented in the following case, communicated by him to the *Ami des Sciences* for December, 1859, are as nearly conclusive as any single instance well can be:

"In the territory of the commune of Labruguière there is a forest of 1,834 hectares [4,530 acres], known by the name of the Forest of Montaut, and belonging to that commune. It extends along the northern slope of the Black Mountains. The soil is granitic, the maximum altitude 1,243 mètres [4,140 feet], and the inclination ranges between 15 and 60 to 100.

"A small current of water, the brook of Caunan, takes its rise in this forest, and receives the waters of two-thirds of its surface. At the lower extremity of the wood and on the stream are several fulleries, each requiring a force of eight horse-power to drive the water-wheels which work the stampers. The commune of Labruguière had been for a long time famous for its opposition to forest laws. Trespasses and abuses of the right of pasturage had converted the wood into an immense waste, so that this vast property now scarcely sufficed to pay the expense of protecting it, and to furnish the inhabitants with a meagre supply of fuel. While the forest was thus ruined, and the soil thus bared, the water, after every abundant rain, made an eruption into the valley, bringing down a great quantity of pebbles which still clog the current of the Caunan. The violence of the floods was sometimes such that they were obliged to stop the machinery for some time. During the summer another inconvenience was felt. If the dry weather continued a little longer than usual, the delivery of water became insignificant. Each fullery could for the most part only employ a single set of stampers, and it was not unusual to see the work entirely suspended.

---

* *The Trees of America*, pp. 50, 51.

"After 1840, the municipal authority succeeded in enlightening the population as to their true interests. Protected by a more watchful supervision, aided by well-managed replantation, the forest has continued to improve to the present day. In proportion to the restoration of the forest, the condition of the manufactories has become less and less precarious, and the action of the water is completely modified. For example, sudden and violent floods, which formerly made it necessary to stop the machinery, no longer occur. There is no increase in the delivery until six or eight hours after the beginning of the rain; the floods follow a regular progression till they reach their maximum, and decrease in the same manner. Finally, the fulleries are no longer forced to suspend work in summer; the water is always sufficiently abundant to allow the employment of two sets of stampers at least, and often even of three.

"This example is remarkable in this respect, that, all other circumstances having remained the same, the changes in the action of the stream can be attributed only to the restoration of the forest—changes which may be thus summed up: diminution of flood-water during rains—increase of delivery at other seasons."

Becquerel and other European writers adduce numerous other cases where the destruction of forests has caused the disappearance of springs, a diminution in the volume of rivers, and a lowering of the level of lakes, and in fact, the evidence in support of the doctrine I have been maintaining on this subject seems to be as conclusive as the nature of the case admits.[*] We cannot, it is true, arrive at the same certainty and precision of result in these inquiries as in those branches of physical research where exact quantitative appreciation is possible, and we must content ourselves with probabilities and approximations. We cannot positively affirm that the precipitation in a given locality is increased by the presence, or lessened by the destruction, of the forest, and from our ignorance of the subterranean circulation of the waters, we cannot predict, with certainty, the drying up of a particular spring as a consequence of the felling of the wood which shelters it; but the general truth, that the flow of springs and the normal volume of rivers rise and fall with the extension and the diminution of the woods where they originate and through which they run, is as well established as any proposition in the science of physical geography.*

---

[*] See, in the *Revue des Eaux et Forêts* for April, 1867, an article entitled *De l'influence des Forêts sur le Régime des Eaux*, and the papers in previous numbers of the same journal therein referred to.

---

* Some years ago it was popularly believed that the volume of the Mississippi, like that of the Volga and other rivers of the Eastern Hemisphere, was diminished by the increased evaporation from its basin and the drying up of the springs in consequence of the felling of the forests in the vicinity of the sources of its eastern affluents. The boatmen of this great river and other intelligent observers now assure us, however, that the mean and normal level of the Mississippi has risen within a few years, and that in consequence the river is navigable at low water for boats of greater draught and at higher points in its course than was the case twenty-five years ago.

This supposed increase of volume has been attributed by some to the recent re-wooding of the prairies, but the plantations thus far made are not yet sufficiently extensive to produce an appreciable effect of this nature; and besides, while young trees have covered some of the prairies, the destruction of the forest has been continued perhaps in a greater proportion in other parts of the basin of the river. A more plausible opinion is that the substitution of ground that is cultivated, and consequently spongy and absorbent, for the natural soil of the prairies, has furnished a reservoir for the rains which are absorbed by the earth and carried gradually to the river by subterranean flow, instead of running off rapidly from the surface, or, as is more probable, instead of evaporating or being taken up by the vigorous herbaceous vegetation which covers the natural prairie.

A phenomenon so contrary to common experience, as would be a permanent increase in the waters of a great river, will not be accepted without the most convincing proofs. The present greater facility of navigation may be attributed to improvements in the model of the boats, to the removing of sandbanks and other impediments to the flow of the waters, or to the confining of these waters in a narrower channel, by extending the embankments of the river, or to yet other causes.

Of the converse proposition, namely, that the planting of new forests gives rise to new springs and restores the regular flow of rivers, I find less of positive proof, however probable it may be that such effects would follow.[*] A reason for the want of evidence on the subject may be, that, under ordinary circumstances, the process of conversion of bare ground to soil with a well-wooded surface is so gradual and slow, and the time required for a fair experiment is consequently so long, that many changes produced by the action of the new geographical element escape the notice and the memory of ordi-

---

So remarkable a change could not have escaped the notice of Humphreys and Abbot, whose most able labors comprise the years 1850–1861, had it occurred during that period or at any former time within the knowledge of the many observers they consulted; but no such fact is noticed in their exhaustive report. However, even if an increase in the volume of the Mississippi, for a period of ten or twenty years, were certain, it would still be premature to consider this increase as normal and constant, since it might very well be produced by causes yet unknown and analogous to those which influence the mysterious advance and retreat of those Alpine ice-rivers, the glaciers. Among such causes we may suppose a long series of rainy seasons in regions where important tributaries have their far-off and almost unknown sources; and with no less probability, we may conceive of the opening of communications with great subterranean reservoirs, which may from year to year empty large quantities of water into the bed of the stream; or the closing up of orifices through which a considerable portion of the water of the river once made its way for the supply of such reservoirs.—See upon this point, Chap. IV., *Of Subterranean Waters; post.*

[*] According to the Report of the Department of Agriculture for February, 1872, it is thought in the Far West that the young plantations have already influenced the water-courses in that region, and it is alleged that ancient river-beds, never known to contain water since the settlement of the country, have begun to flow since these plantations were commenced. See also HAYDEN, *Report on Geological Survey of Wyoming*, 1870, p. 104, and BRYANT, *Forest Trees*, 1871, chap. iv.

In the *Voyage autour du Monde* of the Comte de Beauvoir, chap. x., this passage occurs: Dr. Müller, Director of the Botanic Garden at Melbourne, "has distributed through the interior of Australia millions of seedling trees from his nurseries. Small rivulets are soon formed under the young wood; the results are superb, and the observation of every successive year confirms them. On bare soils he has created, at more than a hundred points, forests and water-courses."

nary observers. The growth of a forest, including the formation of a thick stratum of vegetable mould beneath it, is the work of a generation, its destruction may be accomplished in a day; and hence, while the results of the one process may, for a considerable time, be doubtful if not imperceptible, those of the other are immediate and readily appreciable. Fortunately, the plantation of a wood produces other beneficial consequences which are both sooner realized and more easily estimated; and though he who drops the seed is sowing for a future generation as well as for his own, the planter of a grove may hope himself to reap a fair return for his expenditure and his labor.

Influence of the Forest on Inundations and Torrents.

Inasmuch as it is not yet proved that the forests augment or diminish the precipitation in the regions they principally cover, we cannot positively affirm that their presence or absence increases or lessens the total volume of the water annually delivered by great rivers or by mountain torrents. It is nevertheless certain that they exercise an action on the discharge of the water of rain and snow into the valleys, ravines, and other depressions of the surface, where it is gathered into brooks and finally larger currents, and consequently influence the character of floods, both in rivers and in torrents. For this reason, river inundations and the devastations of torrents, and the geographical effects resulting from them, so far as they are occasioned or modified by the action of forests or of the destruction of the woods, may properly be discussed in this chapter, though they might seem otherwise to belong more appropriately to another division of this work.

Besides the climatic question, which I have already sufficiently discussed, and the obvious inconveniences of a scanty supply of charcoal, of fuel, and of timber for architectural and naval construction and for the thousand other uses to which wood is applied in rural and domestic economy, and in the various industrial processes of civilized life, the attention of

European foresters and public economists has been specially drawn to three points, namely: the influence of the forests on the permanence and regular flow of springs or natural fountains; on inundations by the overflow of rivers; and on the abrasion of soil and the transportation of earth, gravel, pebbles, and even of considerable masses of rock, from higher to lower levels, by torrents. There are, however, connected with this general subject, several other topics of minor or strictly local interest, or of more uncertain character, which I shall have occasion more fully to speak of hereafter.

The first of these three principal subjects—the influence of the woods on springs and other living waters—has been already considered; and if the facts stated in that discussion are well established, and the conclusions I have drawn from them are logically sound, it would seem to follow, as a necessary corollary, that the action of the forest is as important in diminishing the frequency and violence of river-floods as in securing the permanence and equability of natural fountains; for any cause which promotes the absorption and accumulation of the water of precipitation by the superficial strata of the soil, to be slowly given out by infiltration and percolation, must, by preventing the rapid flow of surface-water into the natural channels of drainage, tend to check the sudden rise of rivers, and, consequently, the overflow of their banks, which constitutes what is called inundation.

The surface of a forest, in its natural condition, can never pour forth such deluges of water as flow from cultivated soil. Humus, or vegetable mould, is capable of absorbing almost twice its own weight of water. The soil in a forest of deciduous foliage is composed of humus, more or less unmixed, to the depth of several inches, sometimes even of feet, and this stratum is usually able to imbibe all the water possibly resulting from the snow which at any one time covers, or the rain which in any one shower falls upon, it. But the vegetable mould does not cease to absorb water when it becomes saturated, for it then gives off a portion of its moisture to the mineral earth below, and thus is ready to receive a new supply; and, besides, the bed of leaves not yet converted to mould takes up and retains a very considerable proportion of snow-water, as well as of rain.

The stems of trees, too, and of underwood, the trunks and stumps and roots of fallen timber, the mosses and fungi and the numerous inequalities of the ground observed in all forests, oppose a mechanical resistance to the flow of water over the surface, which sensibly retards the rapidity of its descent down declivities, and diverts and divides streams which may have already accumulated from smaller threads of water.*

---

* In a letter addressed to the Minister of Public Works, after the terrible inundations of 1857, the late Emperor of France thus happily expressed himself: "Before we seek the remedy for an evil, we inquire into its cause. Whence come the sudden floods of our rivers? From the water which falls on the mountains, not from that which falls on the plains. The waters which fall on our fields produce but few rivulets, but those which fall on our roofs and are collected in the gutters, form small streams at once. Now, the roofs are mountains—the gutters are valleys."

"To continue the comparison," observes D'Héricourt, "roofs are smooth and impermeable, and the rain-water pours rapidly off from their surfaces; but this rapidity of flow would be greatly diminished if the roofs were carpeted with mosses and grasses; more still, if they were covered with dry leaves, little shrubs, strewn branches, and other impediments—in short, if they were wooded."—*Annales Forestières, Dec.* 1857, p. 311.

The mosses and fungi play a more important part in regulating the humidity of the air and of the soil than writers on the forest have usually assigned to them. They perish with the trees they grow on; but, in many situations, nature provides a compensation for the tree-mosses and fungi in ground species, which, on cold soils, especially those with a northern exposure, spring up abundantly both before the woods are felled, and when the land is cleared and employed for pasturage, or deserted. These humble plants discharge a portion of the functions appropriated to the wood, and while they render the soil of improved lands much less fit for agricultural use, they, at the same time, prepare it for the growth of a new harvest of trees, when the infertility they produce shall have driven man to abandon it and suffer it to relapse into the hands of nature.

In primitive forests, when the ground is not too moist to admit of a dense growth of trees, the soil is generally so thickly covered with leaves that there is little room for ground mosses and mushrooms. In the more open artificial woods of Europe these forms of vegetation, as well as many more attractive

The value of the forest as a mechanical check to a too rapid discharge of rain-water was exemplified in numerous instances in the great floods of 1866 and 1868, in France and Switzerland, and I refer to the observations made on those occasions as of special importance because no previous inundations in those countries had been so carefully watched and so well described by competent investigators. In the French Department of Lozère, which was among those most severely injured by the inundation of 1866—an inundation caused by diluvial rains, not by melted snow—it was everywhere remarked that "grounds covered with wood sustained no damage even on the steepest slopes, while in cleared and cultivated fields the very soil was washed away and the rocks laid bare by the pouring rain." [*]

The Italian journals of the day state that the province of Brescia and a part of that of Bergamo, which have heretofore been exposed to enormous injury, after every heavy rain, from floods of the four principal streams which traverse them, in a great degree escaped damage in the terrible inundation of October, 1872, and their immunity is ascribed to the forestal improvements executed by the former province, within ten or twelve years, in the Val Camonica and in the upper basins of the other rivers which drain that territory. Similar facts were noticed in the extraordinary floods of September and October, 1868, in the valley of the Upper Rhine, and Coaz makes the interesting observation that not even dense greensward was so efficient a protection to the earth as trees, because the

---

plants, are more frequent than in the native groves of America. See, on cryptogamic and other wood plants, ROSSMÄSSLER, *Der Wald*, pp. 32 *et seqq.*, and on the importance of such vegetables in checking the flow of water, MENGOTTI, *Idraulica Fisica e Sperimentale*, chapters xvi. and xvii. No writer known to me has so well illustrated this function of forest vegetation as Mengotti, though both he and Rossmässler ascribe to plants a power of absorbing water from the atmosphere which they do not possess, or rather can only rarely exercise.

[*] See, for other like observations, an article entitled *Le Reboisement et les Inondations*, in the *Revue des Eaux et Forêts* of September, 1868.

water soaked through the sod and burst it up by hydrostatic pressure.[*]

The importance of the mechanical resistance of the wood to the flow of water *over the surface* has, however, been exaggerated by some writers. Rain-water is generally absorbed by the forest-soil as fast as it falls, and it is only in extreme cases that it gathers itself into a superficial sheet or current overflowing the ground. There is, nevertheless, besides the absorbent power of the soil, a very considerable mechanical resistance to the transmission of water *beneath* the surface through and along the superior strata of the ground. This resistance is exerted by the roots, which both convey the water along their surface downwards, and oppose a closely wattled barrier to its descent along the slope of the permeable strata which have absorbed it.[†]

---

[*] *Die Hochwasser in* 1868 *im Bündnerischen Rheingebiet*, pp. 12, 68.

Observations of Forster, cited by Cézanne from the *Annales Forestières* for 1859, p. 358, are not less important than those adduced in the text. The field of these observations was a slope of 45° divided into three sections, one luxuriantly wooded from summit to base with oak and beech, one completely cleared through its whole extent, and one cleared in its upper portion, but retaining a wooded belt for a quarter of the height of the slope, which was from 1,300 to 1,800 feet above the brook at its foot.

In the first section, comprising six-sevenths of the whole surface, the rains had not produced a single ravine ; in the second, occupying about a tenth of the ground, were three ravines, increasing in width from the summit to the valley beneath, where they had, all together, a cross-section of 600 square feet ; in the third section, of about the same extent as the second, four ravines had been formed, widening from the crest of the slope to the belt of wood, where they gradually narrowed and finally disappeared.

For important observations to the same purpose, see MARCHAND, *Les Torrents des Alpes*, in *Revue des Eaux et Forêts* for September, 1871.

[†] In a valuable report on a bill for compelling the sale of waste communal lands, now pending in the Parliament of Italy, Senator Torelli, an eminent man of science, calculates that four-fifths of the precipitation in the forest are absorbed by the soil, or detained by the obstructions of the surface, only one-fifth being delivered to the rivers rapidly enough to create danger of floods, while in open grounds, in heavy rains, the proportions are reversed. Supposing a rain-fall of four inches, an area measuring 100,000 acres, or a little more

Rivers fed by springs and shaded by woods are comparatively uniform in volume, in temperature, and in chemical composition.[*] Their banks are little abraded, nor are their courses much obstructed by fallen timber, or by earth and gravel washed down from the highlands. Their channels are subject only to slow and gradual changes, and they carry down to the lakes and the sea no accumulation of sand or silt to fill up their outlets, and, by raising their beds, to force them to spread over the low grounds near their mouth.[†]

Causes of Inundations.

The immediate cause of river inundations is the flow of superficial and subterranean waters into the beds of rivers faster than those channels can discharge them. The insufficiency of the channels is occasioned partly by their narrowness and partly by obstructions to their currents, the most frequent of

---

than four American townships, would receive 53,777,777 cubic yards of water. Of this quantity it would retain, or rather detain, if wooded, 41,000,000 yards; if bare, only 11,000,000. The difference of discharge from wooded and unwooded soils is perhaps exaggerated in Col. Torelli's report, but there is no doubt that in very many cases it is great enough to prevent, or to cause, destructive inundations.

[*] Dumont gives an interesting extract from the Misopogon of the Emperor Julian, showing that, in the fourth century, the Seine—the level of which now varies to the extent of thirty feet between extreme high and extreme low water mark—was almost wholly exempt from inundations, and flowed with a uniform current through the whole year. "Ego olim eram in hibernis apud caram Lutetiam, [sic] enim Galli Parisiorum oppidum appellant, quæ insula est non magna, in fluvio sita, qui eam omni ex parte cingit. Pontes sublicii utrinque ad eam ferunt, raròque fluvius minuitur ac crescit; sed qualis æstate, talis esse solet hyeme."—*Des Travaux Publics dans leur Rapports avec l'Agriculture*, p. 361, note.

As Julian was six years in Gaul, and his principal residence was at Paris, his testimony as to the habitual condition of the Seine, at a period when the provinces where its sources originate were well wooded, is very valuable.

[†] Forest rivers seldom if ever form large sedimentary deposits at their points of discharge into lakes or larger streams, such accumulations beginning, or at least advancing far more rapidly, after the valleys are cleared.

which is the deposit of sand, gravel, and pebbles in their beds by torrential tributaries during the floods.*

In accordance with the usual economy of nature, we should presume that she had everywhere provided the means of discharging, without disturbance of her general arrangements or abnormal destruction of her products, the precipitation which she sheds upon the face of the earth. Observation confirms this presumption, at least in the countries to which I confine my inquiries; for, so far as we know the primitive conditions of the regions brought under human occupation within the historical period, it appears that the overflow of river-banks was much less frequent and destructive than at the present day, or, at least, that rivers rose and fell less suddenly, before man had removed the natural checks to the too rapid drainage of the basins in which their tributaries originate. The affluents of rivers draining wooded basins generally transport, and of course let fall, little or no sediment, and hence in such regions the special obstruction to the currents of water-courses to which I have just alluded does not occur. The banks of the rivers and smaller streams in the North American colonies were formerly little abraded by the currents.* Even now the trees come down almost to the water's edge along the rivers, in the larger forests of the United States, and the surface of the streams seems liable to no great change in level or in rapidity of current.†

---

* The extent of the overflow and the violence of the current in river-floods are much affected by the amount of sedimentary matter let fall in their channels by their affluents, which have usually a swifter flow than the main stream, and consequently deposit more or less of their transported material when they join its more slowly-moving waters. Such deposits constitute barriers which at first check the current and raise its level, and of course its violence at lower points is augmented, both by increased volume and by the solid material it carries with it, when it acquires force enough to sweep away the obstruction.—RISLER, *Sur l'Influence des Forêts sur les cours d'eau*, in *Revue des Eaux et Forêts*, 10th January, 1870.

In the flood of 1868 the torrent Illgraben, which had formerly spread its water and its sediment over the surface of a vast cone of dejection, having been forced, by the injudicious confinement of its current to a single channel, to discharge itself more directly into the Rhone, carried down a quantity of gravel, sand, and mud, sufficient to dam that river for a whole hour, and in the same great inundation the flow of the Rhine at Thusis was completely arrested for twenty minutes by a similar discharge from the Nolla. Of course, when the dam yielded to the pressure of the accumulated water, the damage to the country below was far greater than it would have been had the currents of the rivers not been thus obstructed.—MARCHAND, *Les Torrents des Alpes*, in *Revue des Eaux et Forêts*, Sept., 1871.

---

* In primitive countries, running streams are very generally fringed by groves, for almost every river is, as Pliny, *Nat. Hist.*, v. 10, says of the Upper Nile, an *opifex silvarum*, or, to use the quaint and picturesque language of Holland's translation, "makes shade of woods as he goeth."

† A valuable memoir by G. Doni, in the *Rivista Forestale* for October, 1865, p. 438, is one of the best illustrations I can cite of the influence of forests in regulating and equalizing the flow of running water, and of the comparative action of water-courses which drain wooded valleys and valleys bared of trees, with regard to the erosion of their banks and the transportation of sediment.

"The Sestajone," remarks this writer, "and the Lima, are two considerable torrents which collect the waters of two great valleys of the Tuscan Apennines, and empty them into the Serchio. At the junction of these two torrents, from which point the combined current takes the name of Lima, a curious phenomenon is observed, which is in part easily explained. In rainy weather the waters of the Sestajone are in volume only about one-half those of the Lima, and while the current of the Lima is turbid and muddy, that of the Sestajone appears limpid and I might almost say drinkable. In clear weather, on the contrary, the waters of the Sestajone are abundant and about double those of the Lima. Now the extent of the two valleys is nearly equal, but the Sestajone winds down between banks clothed with firs and beeches, while the Lima flows through a valley that has been stripped of trees, and in great part brought under cultivation."

The Sestajone and the Lima are neither of them what is technically termed a torrent—a name strictly applicable only to streams whose current is not derived from springs and perennial, but is the temporary effect of a sudden accumulation of water from heavy rains or from a rapid melting of the snows, while their beds are dry, or nearly so, at other times. The Lima, however, in a large proportion of its course, has the erosive character of a torrent, for the amount of sediment which it carries down, even when it is only moderately swollen by rains, surpasses almost everything of the kind which I have observed, under analogous circumstances, in Italy.

Still more striking is the contrast in the *régime* of the Saint-Phalez and the Combe-d'Yeuse in the Department of Vaucluse, the latter of which became subject to the most violent torrential floods after the destruction of the woods of its basin between 1823 and 1833, but has now been completely subdued, and

Inundations in Winter.

In the Northern United States, although inundations are not very unfrequently produced by heavy rains in the height of summer, it will be found generally true that the most rapid rise of the waters, and, of course, the most destructive "freshets," as they are called in America, are occasioned by the sudden dissolution of the snow before the open ground is thawed in the spring. It frequently happens that a powerful thaw sets in after a long period of frost, and the snow which had been months in accumulating is dissolved and carried off in a few hours. When the snow is deep, it, to use a popular expression, "takes the frost out of the ground" in the woods, and, if it lies long enough, in the fields also. But the heaviest snows usually fall after midwinter, and are succeeded by warm rains or sunshine, which dissolve the snow on the cleared land before it has had time to act upon the frost-bound soil beneath it. In this case, the snow in the woods is absorbed as fast as it melts, by the soil it has protected from freezing, and does not materially contribute to swell the current of the rivers. If the mild weather, in which great snow-storms usually occur, does not continue and become a regular thaw, it is almost sure to be followed by drifting winds, and the inequality with which they distribute the snow over the cleared ground leaves the ridges of the surface-soil comparatively bare, while the depressions are often filled with drifts to the height of many feet. The knolls become frozen to a great depth; succeeding partial thaws melt the surface-snow, and the water runs down into the furrows of ploughed fields, and other artificial and natural hollows, and then often freezes to solid ice. In this state of things, almost the entire surface of the cleared land is impervious to water, and from the absence of trees and the general smoothness of

---

its waters brought to a peaceful flow, by replanting its valley. See LABUSSIÈRE, *Revue Agric. et Forestière de Provence*, 1866, and *Revue des Eaux et Forêts*, 1866.

the ground, it offers little mechanical resistance to superficial currents. If, under these circumstances, warm weather accompanied by rain occurs, the rain and melted snow are swiftly hurried to the bottom of the valleys and gathered to raging torrents.

It ought further to be considered that, though the lighter ploughed soils readily imbibe a great deal of water, yet grass-lands, and all the heavy and tenacious earths, absorb it in much smaller quantities, and less rapidly than the vegetable mould of the forest. Pasture, meadow, and clayey soils, taken together, greatly predominate over sandy ploughed fields, in all large agricultural districts, and hence, even if, in the case we are supposing, the open ground chance to have been thawed before the melting of the snow which covers it, it is already saturated with moisture, or very soon becomes so, and, of course, cannot relieve the pressure by absorbing more water. The consequence is that the face of the country is suddenly flooded with a quantity of melted snow and rain equivalent to a fall of six or eight inches of the latter, or even more. This runs unobstructed to rivers often still-bound with thick ice, and thus inundations of a fearfully devastating character are produced. The ice bursts, from the hydrostatic pressure from below, or is violently torn up by the current, and is swept by the impetuous stream, in large masses and with resistless fury, against banks, bridges, dams, and mills erected near them. The bark of the trees along the rivers is often abraded, at a height of many feet above the ordinary water-level, by cakes of floating ice, which are at last stranded by the receding flood on meadow or ploughland, to delay, by their chilling influence, the advent of the tardy spring.

Another important effect of the removal of the forest shelter in cold climates may be noticed here. We have observed that the ground in the woods either does not freeze at all, or that if frozen it is thawed by the first considerable snow-fall. On the contrary, the open ground is usually frozen when the first spring freshet occurs, but is soon thawed by the warm rain and melting snow. Nothing more effectually disintegrates a cohesive soil than freezing and thawing, and the surface of earth which has just undergone those processes is more subject to erosion by running water than under any other circumstances. Hence more vegetable mould is washed away from cultivated grounds in such climates by the spring floods than by the heaviest rain at other seasons.

In the warm climates of Southern Europe, as I have already said, the functions of the forest, so far as the disposal of the water of precipitation is concerned, are essentially the same at all seasons, and are analogous to those which it performs in the Northern United States in summer. Hence, in the former countries, the winter floods have not the characteristics which mark them in the latter, nor is the conservative influence of the woods in winter relatively so important, though it is equally unquestionable.

If the summer floods in the United States are attended with less pecuniary damage than those of the Loire and other rivers of France, the Po and its tributaries in Italy, the Emme and her sister torrents which devastate the valleys of Switzerland, it is partly because the banks of American rivers are not yet lined with towns, their shores and the bottoms which skirt them not yet covered with improvements whose cost is counted by millions, and, consequently, a smaller amount of property is exposed to injury by inundation. But the comparative exemption of the American people from the terrible calamities which the overflow of rivers has brought on some of the fairest portions of the Old World, is, in a still greater degree, to be ascribed to the fact that, with all our thoughtless improvidence, we have not yet bared all the sources of our streams, not yet overthrown all the barriers which nature has erected to restrain her own destructive energies. Let us be wise in time, and profit by the errors of our older brethren!

The influence of the forest in preventing inundations has been very generally recognized, both as a theoretical inference and as a fact of observation; but the eminent engineer Belgrand

and his commentator Vallès have deduced an opposite result from various facts of experience and from scientific considerations. They contend that the superficial drainage is more regular from cleared than from wooded ground, and that clearing diminishes rather than augments the intensity of inundations. Neither of these conclusions appears to be warranted by their data or their reasoning, and they rest partly upon facts, which, truly interpreted, are not inconsistent with the received opinions on these subjects, partly upon assumptions which are contradicted by experience. Two of these latter are, first, that the fallen leaves in the forest constitute an impermeable covering of the soil over, not through, which the water of rains and of melting snows flows off, and secondly, that the roots of trees penetrate and choke up the fissures in the rocks, so as to impede the passage of water through channels which nature has provided for its descent to lower strata.

As to the first of these, we may appeal to familiar facts within the personal knowledge of every man acquainted with the operations of sylvan nature. Rain-water never, except in very trifling quantities, flows over the leaves in the woods in summer or autumn. Water runs over them only in the spring, in the rare cases when they have been pressed down smoothly and compactly by the weight of the snow—a state in which they remain only until they are dry, when shrinkage and the action of the wind soon roughen the surface so as effectually to stop, by absorption, all flow of water. I have observed that when a sudden frost succeeds a thaw at the close of the winter, after the snow has principally disappeared, the water in and between the layers of leaves sometimes freezes into a solid crust, which allows the flow of water over it. But this occurs only in depressions and on a very small scale; and the ice thus formed is so soon dissolved that no sensible effect is produced on the escape of water from the general surface.

As to the influence of roots upon drainage, we have seen that there is no doubt that they, independently of their action as absorbents, mechanically promote it. Not only does the water of the soil follow them downwards, but their swelling growth powerfully tends to enlarge, not to obstruct, the crevices of rock into which they enter; and as the fissures in rocks are longitudinal, not mere circular orifices, every line of additional width gained by the growth of roots within them increases the area of the crevice in proportion to its length. Consequently, the widening of a fissure to the extent of one inch might give an additional drainage equal to a square foot of open tubing.

The observations and reasonings of Belgrand and Vallès, though their conclusions have not been accepted by many, are very important in one point of view. These writers insist much on the necessity of taking into account, in estimating the relations between precipitation and evaporation, the abstraction of water from the surface and surface-currents, by absorption and infiltration—an element unquestionably of great value, but hitherto much neglected by meteorological inquirers, who have very often reasoned as if the surface-earth were either impermeable to water or already saturated with it; whereas, in fact, it is a sponge, always imbibing humidity and always giving it off, not by evaporation only, but by infiltration and percolation.

The remarkable historical notices of inundations in France in the Middle Ages collected by Champion[*] are considered by many as furnishing proof, that when that country was much more generally covered with wood than it now is, destructive inundations of the French rivers were not less frequent than they are in modern days. But this evidence is subject to this among other objections: we know, it is true, that the forests of certain departments of France were anciently much more extensive than at the present day; but we know also that in many portions of that country the soil has been bared of its forests, and then, in consequence of the depopulation of great provinces, left to reclothe itself spontaneously with trees, many times during the historic period; and our acquaintance with the forest topography of ancient Gaul or of mediæval France is neither sufficiently extensive nor sufficiently minute to permit us to say, with certainty, that the sources of this or that particular river were more or less sheltered by wood at any given time, ancient or mediæval, than at present.* I say the sources of the rivers, because the floods of great rivers are occasioned by heavy rains and snows which fall in the more elevated regions around the primal springs, and not by precipitation in the main valleys or on the plains bordering on the lower course.

---

[*] *Les Inondations en France depuis le VIe siècle jusqu'à nos jours.* 6 vols. 8vo. Paris, 1858–64. See a very able review of this learned and important work by Prof. Messedaglia, read before the Academy of Agriculture at Verona in 1864.

The destructive effects of inundations, considered simply as a mechanical power by which life is endangered, crops destroyed, and the artificial constructions of man overthrown, are very terrible. Thus far, however, the flood is a temporary and by no means an irreparable evil, for if its ravages end here, the prolific powers of nature and the industry of man soon restore what had been lost, and the face of the earth no longer shows traces of the deluge that had overwhelmed it. Inundations have even their compensations. The structures they destroy are replaced by better and more secure erections, and if they sweep off a crop of corn, they not unfrequently leave behind them, as they subside, a fertilizing deposit which enriches the exhausted field for a succession of seasons.† If, then, the too rapid flow of the surface-waters occasioned no other evil than to produce, once in ten years upon the average, an inundation which should destroy the harvest of the low grounds along the rivers, the damage would be too inconsiderable, and of too transitory a character, to warrant the inconveniences and the expense involved in the measures which the most competent judges in many parts of Europe believe the respective governments ought to take to obviate it.

---

* Alfred Maury has, nevertheless, collected, in his erudite and able work, *Les Forêts de la Gaule et de l'ancienne France*, Paris, 1867, an immense amount of statistical detail on the extent, the distribution, and the destruction of the forests of France, but it still remains true that we can very seldom pronounce on the forestal condition of the upper valley of a particular river at the time of a given inundation in the ancient or the mediæval period.

† The productiveness of Egypt has been attributed too exclusively to the fertilizing effects of the slime deposited by the inundations of the Nile; for in that climate a liberal supply of water would produce good crops on almost any ordinary sand, while, without water, the richest soil would yield nothing. The sediment deposited annually is but a very small fraction of an inch in thickness. It is alleged that in quantity it would be hardly sufficient for a good top-dressing, and that in quality it is not chemically distinguishable from the soil inches or feet below the surface. But to deny, as some writers have done, that the slime has any fertilizing properties at all, is as great an

Destructive Action of Torrents.

But the great, the irreparable, the appalling mischiefs which have already resulted, and which threaten to ensue on a still more extensive scale hereafter, from too rapid superficial drainage, are of a properly geographical, we may almost say geological, character, and consist primarily in erosion, displacement, and transportation of the superficial strata, vegetable and mineral—of the integuments, so to speak, with which nature has clothed

---

error as the opposite one of ascribing all the agricultural wealth of Egypt to that single cause of productiveness. Fine soils deposited by water are almost uniformly rich in all climates; those brought down by rivers, carried out into salt-water, and then returned again by the tide, seem to be more permanently fertile than any others. The polders of the Netherland coast are of this character, and the meadows in Lincolnshire, which have been covered with slime by *warping*, as it is called, or admitting water over them at high tide, are remarkably productive.

Recent analysis is said to have detected in the water of the Nile a quantity of organic matter—derived mainly, no doubt, from the decayed vegetation it bears down from its tropical course—sufficiently large to furnish an important supply of fertilizing ingredients to the soil.

It is computed that the Durance—a river fed chiefly by torrents, of great erosive power—carries down annually solid material enough to cover 272,000 acres of soil with a deposit of two-fifths of an inch in thickness, and that this deposit contains, in the combination most favorable to vegetation, more azote than 110,000 tons of guano, and more carbon than 121,000 acres of woodland would assimilate in a year. ELISÉE RECLUS, *La Terre*, vol. i., p. 467. On the chemical composition, quantity, and value of the solid matter transported by river, see HERVÉ MANGON, *Sur l'Emploi des Eaux dans les Irrigations*, 8vo. Paris, 1869, pp. 132 *et seqq.* DUPONCHEL, *Traité d'Hydraulique et de Géologie Agricoles*. Paris, 1868, chap. i., xii., and xiii.

the skeleton frame-work of the globe. It is difficult to convey by description an idea of the desolation of the regions most exposed to the ravages of torrent and of flood; and the thousands who, in these days of swift travel, are whirled by steam near or even through the theatres of these calamities, have but rare and imperfect opportunities of observing the destructive causes in action. Still more rarely can they compare the past with the actual condition of the provinces in question, and trace the progress of their conversion from forest-crowned hills, luxuriant pasture grounds, and abundant cornfields and vineyards well watered by springs and fertilizing rivulets, to bald mountain ridges, rocky declivities, and steep earth-banks furrowed by deep ravines with beds now dry, now filled by torrents of fluid mud and gravel hurrying down to spread themselves over the plain, and dooming to everlasting barrenness the once productive fields. In surveying such scenes, it is difficult to resist the impression that nature pronounced a primal curse of perpetual sterility and desolation upon these sublime but fearful wastes, difficult to believe that they were once, and but for the folly of man might still be, blessed with all the natural advantages which Providence has bestowed upon the most favored climes. But the historical evidence is conclusive as to the destructive changes occasioned by the agency of man upon the flanks of the Alps, the Apennines, the Pyrenees, and other mountain ranges in Central and Southern Europe, and the progress of physical deterioration has been so rapid that, in some localities, a single generation has witnessed the beginning and the end of the melancholy revolution.

I have stated, in a general way, the nature of the evils in question, and of the processes by which they are produced; but I shall make their precise character and magnitude better understood by presenting some descriptive and statistical details of facts of actual occurrence. I select for this purpose the south-eastern portion of France, not because that territory has suffered more severely than some others, but because its deterioration is comparatively recent, and has been watched and described by very competent and trustworthy observers, whose reports are more easily accessible than those published in other countries.[*]

The provinces of Dauphiny and Provence comprise a territory of fourteen or fifteen thousand square miles, bounded north-west by the Isere, north-east and east by the Alps, south by the Mediterranean, west by the Rhone, and extending from 42° to about 45° of north latitude. The surface is generally hilly and even mountainous, and several of the peaks in Dauphiny rise above the limit of perpetual snow. Except upon the mountain ridges, the climate, as compared with that of the United States in the same latitude, is extremely mild. Little snow falls, except upon the higher mountains, the frosts are light, and the summers long, as might, indeed, be inferred from the vegetation; for in the cultivated districts, the vine and the fig everywhere flourish; the olive thrives as far north as 43½°, and upon the coast grow the orange, the lemon, and the date-palm. The forest trees, too, are of southern type, umbrella pines, various species of evergreen oaks, and many other trees and shrubs of persistent broad-leaved foliage, characterizing the landscape.

The rapid slope of the mountains naturally exposed these provinces to damage by torrents, and the Romans diminished their injurious effects by erecting, in the beds of ravines, barriers of rocks loosely piled up, which permitted a slow escape of the water, but compelled it to deposit above the dikes the earth and gravel with which it was charged.[†] At a later period the Crusaders brought home from Palestine, with much other knowledge gathered from the wiser Moslems, the art of securing the hillsides and making them productive by terracing and irrigation. The forests which covered the mountains secured an abundant flow of springs, and the process of clearing the soil went on so slowly that, for centuries, neither the want of timber and fuel, nor the other evils about to be depicted, were seriously felt. Indeed, throughout the Middle Ages, these provinces were well wooded, and famous for the fertility and abundance, not only of the low grounds, but of the hills.

---

[*] Streffleur (*Ueber die Natur und die Wirkungen der Wildbäche*, p. 3) maintains that all the observations and speculations of French authors on the nature of torrents had been anticipated by Austrian writers. In proof of this assertion he refers to the works of Franz von Zallinger, 1778, Von Arretin, 1808, Franz Duile, 1826, all published at Innsbruck, and HAGEN'S *Beschreibung neuerer Wasserbauwerke*, Königsberg, 1826, none of which works are known to me. It is evident, however, that the conclusions of Surell and other French writers whom I cite, are original results of personal investigation, and not borrowed opinions.

[†] Whether Palissy was acquainted with this ancient practice, or whether it was one of those original suggestions of which his works are so full, I know

Such was the state of things at the close of the fifteenth century. The statistics of the seventeenth show that while there had been an increase of prosperity and population in Lower Provence, as well as in the correspondingly situated parts of the other two provinces I have mentioned, there was an alarming decrease both in the wealth and in the population of Upper Provence and Dauphiny, although, by the clearing of the forests, a great extent of plough-land and pasturage had been added to the soil before reduced to cultivation. It was found, in fact, that the augmented violence of the torrents had swept away, or buried in sand and gravel, more land than had been reclaimed by clearing; and the taxes computed by fires or habitations underwent several successive reductions in consequence of the gradual abandonment of the wasted soil by its starving occupants. The growth of the large towns on and near the Rhone and the coast, their advance in commerce and industry, and the

---

not, but in his treatise, *Des Eaux et Fontaines*, he thus recommends it, by way of reply to the objections of "Théorique," who had expressed the fear that "the waters which rush violently down from the heights of the mountain would bring with them much earth, sand, and other things," and thus spoil the artificial fountain that "Practique" was teaching him to make: "And for hindrance of the mischiefs of great waters which may be gathered in few hours by great storms, when thou shalt have made ready thy parterre to receive the water, thou must lay great stones athwart the deep channels which lead to thy parterre. And so the force of the rushing currents shall be deadened, and thy water shall flow peacefully into his cisterns."—*Œuvres Complètes*, p. 173.

consequently enlarged demand for agricultural products, ought naturally to have increased the rural population and the value of their lands ; but the physical decay of the uplands was such that considerable tracts were deserted altogether, and in Upper Provence, the fires which in 1471 counted 897, were reduced to 747 in 1699, to 728 in 1733, and to 635 in 1776.*

Surell—whose admirable work, *Étude sur les Torrents des Hautes Alpes*, first published in 1841,† presents a most appalling picture of the desolations of the torrent, and, at the same time, the most careful studies of the history and essential character of this great evil—in speaking of the valley of Dévoluy, on page 152, says: "Everything concurs to show that it was anciently wooded. In its peat-bogs are found buried trunks of trees, monuments of its former vegetation. In the framework of old houses, one sees enormous timber, which is no longer to be found in the district. Many localities, now completely bare, still retain the name of 'wood,' and one of them is called, in old deeds, *Comba nigra* [Black forest or dell], on account of its dense woods. These and many other proofs confirm the local traditions which are unanimous on this point.

"There, as everywhere in the Upper Alps, the clearings began on the flanks of the mountains, and were gradually extended into the valleys and then to the highest accessible peaks. Then followed the Revolution, and caused the destruction of the remainder of the trees which had thus far escaped the woodman's axe."

In a note to this passage the writer says: "Several persons have told me that they had lost flocks of sheep, by straying, in the forests of Mont Auroux, which covered the flanks of the mountain from La Cluse to Agnères. These declivities are now as bare as the palm of the hand."

---

* These facts I take from the *La Provence au point de vue des Bois, des Torrents et des Inondations*, of Charles de Ribbe, one of the highest authorities.

† A second edition of this work, with an additional volume of great value by Ernest Cézanne, was published at Paris, in two 8vo volumes, in 1871-72.

The ground upon the steep mountains being once bared of trees, and the underwood killed by the grazing of horned cattle, sheep, and goats, every depression becomes a water-course. "Every storm," says Surell, page 153, "gives rise to a new torrent.* Examples of such are shown, which, though not yet three years old, have laid waste the finest fields of their valleys, and whole villages have narrowly escaped being swept into ravines formed in the course of a few hours. Sometimes the flood pours in a sheet over the surface, without ravine or even bed, and ruins extensive grounds, which are abandoned forever."

I cannot follow Surell in his description and classification of torrents, and I must refer the reader to his instructive work for a full exposition of the theory of the subject. In order, however, to show what a concentration of destructive energies may be effected by felling the woods that clothe and support the sides of mountain abysses, I cite his description of a valley descending from the Col Isoard, which he calls "a complete type of a basin of reception," that is, a gorge which serves as a common point of accumulation and discharge for the waters of several lateral torrents. "The aspect of the monstrous channel," says he, "is frightful. Within a distance of less than two English miles, more than sixty torrents hurl into the depths of the gorge the débris torn from its two flanks. The smallest of these secondary torrents, if transferred to a fertile valley, would be enough to ruin it."

The eminent political economist Blanqui, in a memoir read before the Academy of Moral and Political Science on the 25th of November, 1843, thus expresses himself: "Important as are the causes of impoverishment already described, they are not to be compared to the consequences which have followed from the two inveterate evils of the Alpine provinces of France, the extension of clearing and the ravages of torrents. . . The most important result of this destruction is this: that the agricultural capital, or rather the ground itself—which, in a rapidly increasing degree, is daily swept away by the waters—is totally lost. Signs of unparalleled destitution are visible in all the mountain zone, and the solitudes of those districts are assuming an indescribable character of sterility and desolation. The gradual destruction of the woods has, in a thousand localities, annihilated at once the springs and the fuel. Between Grenoble and Briançon, in the valley of the Romanche, many villages are so destitute of wood that they are reduced to the necessity of baking their bread with sun-dried cow-dung, and even this they can afford to do but once a year.

---

* No attentive observer can frequent the southern flank of the Piedmontese Alps or the French province of Dauphiny, for half a dozen years, without witnessing with his own eyes the formation and increase of new torrents. I can bear personal testimony to the conversion of more than one grassy slope into the bed of a furious torrent by baring the hills above of their woods.

"Whoever has visited the valley of Barcelonette, those of Embrun, and of Verdun, and that Arabia Petræa of the department of the Upper Alps, called Dévoluy, knows that there is no time to lose—that in fifty years from this date France will be separated from Savoy, as Egypt from Syria, by a desert." *

It deserves to be specially noticed that the district here referred to, though now among the most hopelessly waste in France, was very productive even down to so late a period as the commencement of the French Revolution. Arthur Young, writing in 1789, says: "About Barcelonette and in the highest parts of the mountains, the hill-pastures feed a million of sheep, besides large herds of other cattle;" and he adds: "With such a soil and in such a climate, we are not to suppose a country barren because it is mountainous. The valleys I have visited are, in general, beautiful."† He ascribes the

---

* Ladoucette says the peasant of Dévoluy "often goes a distance of five hours over rocks and precipices for a single [man's] load of wood;" and he remarks on another page, that "the justice of peace of that canton had, in the course of forty-three years, but once heard the voice of the nightingale."—*Histoire, etc., des Hautes Alpes*, pp. 220, 434.

† The valley of Embrun, now almost completely devastated, was once remarkable for its fertility. In 1806, Héricart de Thury said of it: "In this

same character to the provinces of Dauphiny, Provence, and Auvergne, and, though he visited, with the eye of an attentive and practised observer, many of the scenes since blasted with the wild desolation described by Blanqui, the Durance and a part of the course of the Loire are the only streams he mentions as inflicting serious injury by their floods. The ravages of the torrents had, indeed, as we have seen, commenced earlier in some other localities, but we are authorized to infer that they were, in Young's time, too limited in range, and relatively too insignificant, to require notice in a general view of the provinces where they have now ruined so large a proportion of the soil.

But I resume my citations.

"I do not exaggerate," says Blanqui. "When I shall have finished my description and designated localities by their names, there will rise, I am sure, more than one voice from the spots themselves, to attest the rigorous exactness of this picture of their wretchedness. I have never seen its equal even in the Kabyle villages of the province of Constantine; for there you can travel on horseback, and you find grass in the spring, whereas in more than fifty communes in the Alps there is absolutely nothing.

"The clear, brilliant, Alpine sky of Embrun, of Gap, of Barcelonette, and of Digne, which for months is without a cloud, produces droughts interrupted only by diluvial rains like those of the tropics. The abuse of the right of pasturage and the felling of the woods have stripped the soil of all its grass and all its trees, and the scorching sun bakes it to the consistence of porphyry. When moistened by the rain, as it has neither support nor cohesion, it rolls down to the valleys, sometimes in floods resembling black, yellow, or reddish lava, sometimes in streams of pebbles, and even huge blocks of stone, which pour down with a frightful roar, and in their

---

magnificent valley nature had been prodigal of her gifts. Its inhabitants have blindly revelled in her favors, and fallen asleep in the midst of her profusion." —BECQUEREL, *Des Climats*, etc., p. 314.

swift course exhibit the most convulsive movements. If you overlook from an eminence one of these landscapes furrowed with so many ravines, it presents only images of desolation and of death. Vast deposits of flinty pebbles, many feet in thickness, which have rolled down and spread far over the plain, surround large trees, bury even their tops, and rise above them, leaving to the husbandman no longer a ray of hope. One can imagine no sadder spectacle than the deep fissures in the flanks of the mountains, which seem to have burst forth in eruption to cover the plains with their ruins. These gorges, under the influence of the sun which cracks and shivers to fragments the very rocks, and of the rain which sweeps them down, penetrate deeper and deeper into the heart of the mountain, while the beds of the torrents issuing from them are sometimes raised several feet in a single year, by the débris, so that they reach the level of the bridges, which, of course, are then carried off. The torrent-beds are recognized at a great distance, as they issue from the mountains, and they spread themselves over the low grounds, in fan-shaped expansions, like a mantle of stone, sometimes ten thousand feet wide, rising high at the centre, and curving towards the circumference till their lower edges meet the plain.

"Such is their aspect in dry weather. But no tongue can give an adequate description of their devastations in one of those sudden floods which resemble, in almost none of their phenomena, the action of ordinary river-water. They are now no longer overflowing brooks, but real seas, tumbling down in cataracts, and rolling before them blocks of stone, which are hurled forwards by the shock of the waves like balls shot out by the explosion of gunpowder. Sometimes ridges of pebbles are driven down when the transporting torrent does not rise high enough to show itself, and then the movement is accompanied with a roar louder than the crash of thunder. A furious wind precedes the rushing water and announces its approach. Then comes a violent eruption, followed by a flow of muddy waves, and after a few hours all returns to the dreary silence which at periods of rest marks these abodes of desolation.*

"The elements of destruction are increasing in violence. The devastation advances in geometrical progression as the higher slopes are bared of their wood, and 'the ruin from above,' to use the words of a peasant, 'helps to hasten the desolation below.'

"The Alps of Provence present a terrible aspect. In the more equable climate of Northern France, one can form no conception of those parched mountain gorges where not even a bush can be found to shelter a bird, where, at most, the wanderer sees in summer here and there a withered lavender, where all the springs are dried up, and where a dead silence, hardly broken by even the hum of an insect, prevails. But if a storm bursts forth, masses of water suddenly shoot from the mountain heights into the shattered gulfs, waste without irrigating, deluge without refreshing the soil they overflow in their swift descent, and leave it even more seared than it was from want of moisture. Man at last retires from the fearful desert, and I have, the present season, found not a living soul in districts where I remember to have enjoyed hospitality thirty years ago."

In 1853, ten years after the date of Blanqui's memoir, M. de Bonville, prefect of the Lower Alps, addressed to the Government a report in which the following passages occur:

"It is certain that the productive mould of the Alps, swept off by the increasing violence of that curse of the mountains, the torrents, is daily diminishing with fearful rapidity. All our Alps are wholly, or in large proportion, bared of wood. Their soil, scorched by the sun of Provence, cut up by the hoofs of the sheep, which, not finding on the surface the grass they require for their sustenance, gnaw and scratch the ground in search of roots to satisfy their hunger, is periodically washed and carried off by melting snows and summer storms.

---

* These explosive gushes of mud and rock appear to be occasioned by the caving-in of large masses of earth from the banks of the torrent, which dam up the stream and check its flow until it has acquired volume enough to burst the barrier and carry all before it. In 1827, such a sudden eruption of a torrent, after the current had appeared to have ceased, swept off forty-two houses and drowned twenty-eight persons in the village of Goncelin, near Grenoble, and buried with rubbish a great part of the remainder of the village.

The French traveller, D'Abbadie, relates precisely similar occurrences as not unfrequent in the mountains of Abyssinia.—SURELL, *Études*, *etc.*, 2d edition, pp. 224, 295.

"I will not dwell on the effects of the torrents. For sixty years they have been too often depicted to require to be further discussed, but it is important to show that their ravages are daily extending the range of devastation. The bed of the Durance, which now in some places exceeds a mile and a quarter in width, and, at ordinary times, has a current of water less than eleven yards wide, shows something of the extent of the damage.* Where, ten years ago, there were still woods and cultivated grounds to be seen, there is now but a vast torrent; there is not one of our mountains which has not at least one torrent, and new ones are daily forming.

"An indirect proof of the diminution of the soil is to be found in the depopulation of the country. In 1852 I reported to the General Council that, according to the census of that year, the population of the department of the Lower Alps had fallen off no less than 5,000 souls in the five years between 1846 and 1851.

"Unless prompt and energetic measures are taken, it is easy to fix the epoch when the French Alps will be but a desert. The interval between 1851 and 1856 will show a further decrease of population. In 1862 the ministry will announce a continued and progressive reduction in the number of acres devoted to agriculture; every year will aggravate the evil, and in half a century France will count more ruins, and a department the less."

---

* In the days of the Roman Empire the Durance was a navigable, or at least a boatable, river, with a commerce so important that the boatmen upon it formed a distinct corporation.—LADOUCETTE, *Histoire, etc., des Hautes Alpes*, p. 354.

Even as early as 1789 the Durance was computed to have already covered with gravel and pebbles not less than 130,000 acres, "which, but for its inundations, would have been the finest land in the province."—ARTHUR YOUNG, *Travels in France*, vol. i., ch. i.

Time has verified the predictions of De Bonville. The later census returns show a progressive diminution in the population of the departments of the Lower Alps, the Isère, Drome, Ariège, the Upper and the Lower Pyrenees, Lozère, the Ardennes, Doubs, the Vosges, and, in short, in all the provinces formerly remarkable for their forests. This diminution is not to be ascribed to a passion for foreign emigration, as in Ireland, and in parts of Germany and of Italy; it is simply a transfer of population from one part of the empire to another, from soils which human folly has rendered uninhabitable, by ruthlessly depriving them of their natural advantages and securities, to provinces where the face of the earth was so formed by nature as to need no such safeguards, and where, consequently, she preserves her outlines in spite of the wasteful improvidence of man.*

Floods of the Ardèche.

The River Ardèche, in the French department of that name, has a perennial current in a considerable part of its course, and therefore is not, technically speaking, a torrent; but the peculiar character and violence of its floods is due to the action of the torrents which discharge themselves into it in its upper valley, and to the rapidity of the flow of the water of precipitation from the surface of a basin now almost bared of its once luxuriant woods.* A notice of these floods may therefore not inappropriately be introduced in this place.

---

* Between 1851 and 1856 the population of Languedoc and Provence had increased by 101,000 souls. The augmentation, however, was wholly in the provinces of the plains, where all the principal cities are found. In these provinces the increase was 204,000, while in the mountain provinces there was a diminution of 103,000. The reduction of the area of arable land is perhaps even more striking. In 1842 the department of the Lower Alps possessed 99,000 hectares, or nearly 245,000 acres, of cultivated soil. In 1852 it had but 74,000 hectares. In other words, in ten years 25,000 hectares, or 61,000 acres, had been washed away, or rendered worthless for cultivation, by torrents and the abuses of pasturage.—CLAVÉ, *Études*, pp. 66, 67.

The floods of the Ardèche and other mountain streams are attended with greater immediate danger to life and property than those of rivers of less rapid flow, because their currents are more impetuous, and they rise more suddenly and with less previous warning. At the same time, their ravages are confined within narrower limits, the waters retire sooner to their accustomed channel, and the danger is more quickly over, than in the case of inundations of larger rivers. The Ardèche drains a basin of 600,238 acres, or a little less than nine hundred and thirty-eight square miles. Its remotest source is about seventy-five miles, in a straight line, from its junction with the Rhone, and springs at an elevation of four thousand feet above that point. At the lowest stage of the river, the bed of the Chassezac, its largest and longest tributary, is in many places completely dry on the surface—the water being sufficient only to supply the subterranean channels of infiltration—and the Ardèche itself is almost everywhere fordable, even below the mouth of the Chassezac. But in floods, the river has sometimes risen more than sixty feet at the Pont d'Arc, a natural arch of two hundred feet chord, which spans the stream below its junction with all its important affluents. At the height of the inundation of 1857, the quantity of water passing this point—after deducting thirty per cent. for material transported with the current and for irregularity of flow—was estimated at 8,845 cubic yards to the second, and between twelve o'clock at noon on the 10th of September of that year and ten o'clock the next morning, the water discharged through the passage in question amounted to more than 450,000,000 cubic yards. This quantity, distributed equally through the basin of the river, would cover its entire area to a depth of more than five inches.

---

* The original forests in which the basin of the Ardèche was rich have been rapidly disappearing for many years, and the terrific violence of the inundations which are now laying it waste is ascribed, by the ablest investigators, to that cause. In an article inserted in the *Annales Forestières* for 1843, quoted by Hohenstein, *Der Wald*, p. 177, it is said that about one-third of the area of the department had already become absolutely barren, in consequence of clearing, and that the destruction of the woods was still going on with great rapidity. New torrents were constantly forming, and they were estimated to have covered more than 70,000 acres of good land, or one-eighth of the surface of the department, with sand and gravel.

The Ardèche rises so suddenly that, in the inundation of 1846, the women who were washing in the bed of the river had not time to save their linen, and barely escaped with their lives, though they instantly fled upon hearing the roar of the approaching flood. Its waters and those of its affluents fall almost as rapidly, for in less than twenty-four hours after the rain has ceased in the Cévennes, where it rises, the Ardèche returns within its ordinary channel, even at its junction with the Rhone. In the flood of 1772, the water at La Beaume de Ruoms, on the Beaume, a tributary of the Ardèche, rose thirty-five feet above low water, but the stream was again fordable on the evening of the same day. The inundation of 1827 was, in this respect, exceptional, for it continued three days, during which period the Ardèche poured into the Rhone 1,305,000,000 cubic yards of water.

The Nile delivers into the sea 101,000 cubic feet or 3,741 cubic yards per second, on an average of the whole year.* This is equal to 323,222,400 cubic yards per day. In a single day of flood, then, the Ardèche, a river too insignificant to be known except in the local topography of France, contributed to the Rhone once and a half, and for three consecutive days once and one third, as much as the average delivery of the Nile during the same periods, though the basin of the latter river probably contains 1,000,000 square miles of surface, or more than one thousand times as much as that of the former.

---

* Sir JOHN F. W. HERSCHEL, citing Talabot as his authority, *Physical Geography* (24).

In an elaborate paper on "Irrigation," printed in the *United States Patent Report* for 1860, p. 169, it is stated that the volume of water poured into the Mediterranean by the Nile in twenty-four hours, at low water, is 150,566,392,368 cubic mètres; at high water, 705,514,667,440 cubic mètres. Taking the mean of these two numbers, the average daily delivery of the Nile would be 428,081,059,808 cubic mètres, or more than 550,000,000,000 cubic yards. There is some enormous mistake, probably a typographical error, in this statement, which makes the delivery of the Nile seventeen hundred times as great as computed by Talabot, and more than physical geographers have estimated the quantity supplied by all the rivers on the face of the globe.

The average annual precipitation in the basin of the Ardèche is not greater than in many other parts of Europe, but excessive quantities of rain frequently fall in that valley in the autumn. On the 9th of October, 1827, there fell at Joyeuse, on the Beaume, no less than thirty-one inches between three o'clock in the morning and midnight. Such facts as this explain the extraordinary suddenness and violence of the floods of the Ardèche, and the basins of many other tributaries of the Rhone exhibit meteorological phenomena not less remarkable.*

---

* The Drac, a torrent emptying into the Isère a little below Grenoble, has discharged 5,200, the Isère, which receives it, 7,800 cubic yards, and the Durance, above its junction with the Isère, an equal quantity, per second.—MONTLUISANT, *Note sur les Dessèchements, etc.*, *Annales des Ponts et Chaussées*, 1833, 2me sémestre, p. 288.

The Upper Rhone, which drains a basin of about 1,900 square miles, including seventy-one glaciers, receives many torrential affluents, and rain-storms and thaws are sometimes extensive enough to affect the whole tributary system of its narrow valley. In such cases its current swells to a great volume, but previously to the floods of the autumn of 1868 it was never known to reach a discharge of 2,600 cubic yards to the second. On the 28th of September in that year, however, its delivery amounted to 3,700 cubic yards to the second, which is about equal to the mean discharge of the Nile.—*Berichte der Experten-Commission über die Ueberschwemmungen im Jahr* 1868, pp. 174, 175.

The floods of some other French rivers, which have a more or less torrential character, scarcely fall behind those of the Rhone. The Loire, above Roanne, has a basin of 2,471 square miles, or about twice and a half the area of that of the Ardèche. In some of its inundations it has delivered above 9,500 cubic yards per second, or 400 times its low-water discharge.—BELGRAND, *De l'Influence des Forêts, etc.*, *Annales des Ponts et Chaussées*, 1854, 1er sémestre, p. 15, note.

The ordinary low-water discharge of the Seine at Paris is nearly 100 cubic yards per second. Belgrand gives a list of eight floods of that river within the last two centuries, in which it has delivered thirty times that quantity.

The Rhone, therefore, is naturally subject to great and sudden inundations, and the same remark may be applied to most of the principal rivers of France, because the geographical character of all of them is approximately the same.

The volume of water in the floods of most great rivers is determined by the degree in which the inundations of the different tributaries are coincident in time. Were all the affluents of the Lower Rhone to pour their highest annual floods into its channel at once—as the smaller tributaries of the Upper Rhone sometimes do—were a dozen Niles to empty themselves into its bed at the same moment, its water would rise to a height and rush with an impetus that would sweep into the Mediterranean the entire population of its banks, and all the works that man has erected upon the plains which border it. But such a coincidence can never happen. The tributaries of this river run in very different directions, and some of them are swollen principally by the melting of the snows about their sources, others almost exclusively by heavy rains. When a damp southeast wind blows up the valley of the Ardèche, its moisture is condensed, and precipitated in a deluge upon the mountains which embosom the headwaters of that stream, thus producing a flood, while a neighboring basin, the axis of which lies transversely or obliquely to that of the Ardèche, is not at all affected.[*]

---

[*] "There is no example of a coincidence between great floods of the Ardèche and of the Rhone, all the known inundations of the former having taken place when the latter was very low."—MARDIGNY, *Mémoire sur les Inondations des Rivières de l'Ardèche*, p. 26.

The same observation may be applied to the tributaries of the Po, their floods being generally successive, not contemporaneous. The swelling of the affluents of the Amazon, and indeed of most large rivers, is regulated by a similar law. See MESSEDAGLIA, *Analisi dell' opera di Champion*, etc., p. 103.

The floods of the affluents of the Tiber form an exception to this law, being generally coincident, and this is one of the explanations of the frequency of destructive inundations in that river.—LOMBARDINI, *Guida allo Studio dell' Idrologia*, ff. 68; same author, *Esame degli studi sul Tevere.*

I take this occasion to acknowledge myself indebted to Mardigny's interesting memoir just quoted for all the statements I make respecting the floods of the Ardèche, except the comparison of the volume of its waters with that of the Nile.

It is easy to see that the damage occasioned by such floods as I have described must be almost incalculable, and it is by no means confined to the effects produced by overflow and the mechanical force of the superficial currents. In treating of the devastations of torrents, I have hitherto confined myself principally to the erosion of surface and the transportation of mineral matter to lower grounds by them. The general action of torrents, as thus far shown, tends to the ultimate elevation of their beds by the deposit of the earth, gravel, and stone conveyed by them; but until they have thus raised their outlets so as sensibly to diminish the inclination of their channels—and sometimes when extraordinary floods give the torrents momentum enough to sweep away the accumulations which they have themselves heaped up—the swift flow of their currents, aided by the abrasion of the rolling rocks and gravel, scoops their beds constantly deeper, and they consequently not only undermine their banks, but frequently sap the most solid foundations which the art of man can build for the support of bridges and hydraulic structures.*

In the inundation of 1857, the Ardèche destroyed a stone bridge near La Beaume, which had been built about eighty years before. The resistance of the piers, which were erected on piles, the channel at that point being of gravel, produced an eddying current that washed away the bed of the river above them, and the foundation, thus deprived of lateral support, yielded to the weight of the bridge, and the piles and piers fell up-stream.

---

* In some cases where the bed of rapid Alpine streams is composed of very hard rock—as is the case in many of the valleys once filled by ancient glaciers—and especially where they are fed by glaciers not overhung by crumbling cliffs, the channel may remain almost unchanged for centuries. This is observable in many of the tributaries of the Dora Baltea, which drains the valley of Aosta. Several of these small rivers are spanned by more or less perfect Roman bridges—one of which, that over the Lys at Pont St. Martin, is still in good repair and in constant use. An examination of the rocks on which the abutments of this and some other similar structures are founded, and of the channels of the rivers they cross, shows that the beds of the streams cannot have been much elevated or depressed since the bridges were built. In other cases, as at the outlet of the Val Tournanche at Chatillon, where a single rib of a Roman bridge still remains, there is nothing to forbid the supposition that the deep excavation of the channel may have been partly effected at a much later period.

The Roman aqueduct known as the Pont du Gard, near Nismes, was built, in all probability, nineteen centuries ago. The bed of the river Gardon, a rather swift stream, which flows beneath it, can have suffered but a slight depression since the piers of the aqueduct were founded.

By a curious law of compensation, the stream which, at flood, scoops out cavities in its bed, often fills them up again as soon as the diminished velocity of the current allows it to let fall the sand and gravel with which it is charged, so that when the waters return to their usual channel, the bottom shows no sign of having been disturbed. In a flood of the Escontay, a tributary of the Rhone, in 1846, piles driven sixteen feet into its gravelly bed for the foundation of a pier were torn up and carried off, and yet, when the river had fallen to low-water mark, the bottom at that point appeared to have been raised higher than it was before the flood, by new deposits of sand and gravel, while the cut stones of the half-built pier were found buried to a great depth in the excavation which the water had first washed out. The gravel with which rivers thus restore the level of their beds is principally derived from the crushing of the rocks brought down by the mountain torrents, and the destructive effects of inundations are immensely diminished by this reduction of large stones to minute fragments. If the blocks hurled down from the cliffs were transported unbroken to the channels of large rivers, the mechanical force of their movement would be irresistible. They would overthrow the strongest barriers, spread themselves over a surface as wide as the flow of the waters, and convert the most smiling valleys into scenes of the wildest desolation.

As I have before remarked, I have taken my illustrations of the action of torrents and mountain streams principally from French authorities, because the facts recorded by them are chiefly of recent occurrence, and as they have been collected with much care and described with great fulness of detail, the information furnished by them is not only more trustworthy, but both more complete and more accessible than that which can be gathered from any other source. It is not to be supposed, however, that the countries adjacent to France have escaped the consequences of a like improvidence. The southern flanks of the Alps, and, in a less degree, the northern slope of these mountains and the whole chain of the Pyrenees, afford equally striking examples of the evils resulting from the wanton sacrifice of nature's safeguards. But I can afford space for few details, and as an illustration of the extent of these evils in Italy, I shall barely observe that it was calculated ten years ago that four-tenths of the area of the Ligurian provinces had been washed away or rendered incapable of cultivation in consequence of the felling of the woods.*

Highly colored as these pictures seem, they are not exaggerated, although the hasty tourist through Southern France, Switzerland, the Tyrol, and Northern Italy, finding little in his high-road experiences to justify them, might suppose them so. The lines of communication by locomotive-train and diligence lead generally over safer ground, and it is only when they ascend the Alpine passes and traverse the mountain chains, that scenes somewhat resembling those just described fall under the eye of the ordinary traveller. But the extension of the sphere of devastation, by the degradation of the mountains and the transportation of their débris, is producing analogous effects upon the lower ridges of the Alps and the plains which skirt them; and even now one needs but an hour's departure from some great thoroughfares to reach sites where the genius of destruction revels as wildly as in the most frightful of the abysses which Blanqui has painted.†

---

* *Annali di Agricoltura, Industria e Commercio*, vol. i., p. 77. Similar instances of the erosive power of running water might be collected by hundreds from the narratives of travellers in warm countries. The energy of the torrents of the Himalayas is such that the brothers Schlagintweit believe that they will cut gorges through that lofty chain wide enough to admit the passage of currents of warm wind from the south, and thereby modify the climate of the countries lying to the north of the mountains.

† The Skalära-Tobel, for instance, near Coire. See the description of this

There is one effect of the action of torrents which few travellers on the Continent are heedless enough to pass without notice. I refer to the elevation of the beds of mountain streams in consequence of the deposit of the débris with which they are charged. To prevent the spread of sand and gravel over

---

and other like scenes in BERLEPSCH, *Die Alpen*, pp. 169 *et seqq.*, or in Stephen's English translation.

About an hour from Thusis, on the Splügen road, "opens the awful chasm of the Nolla which a hundred years ago poured its peaceful waters through smiling meadows protected by the wooded slopes of the mountains. But the woods were cut down and with them departed the rich pastures, the pride of the valley, now covered with piles of rock and rubbish swept down from the mountains. This result is the more to be lamented as it was entirely compassed by the improvidence of man in thinning the forests."—MORELL, *Scientific Guide to Switzerland*, p. 100."

The recent change in the character of the Mella—a river anciently so remarkable for the gentleness of its current that it was specially noticed by Catullus as flowing *molli flumine*—deserves more than a passing remark. This river rises in the mountain-chain east of Lake Iseo, and traversing the district of Brescia, empties into the Oglio after a course of about seventy miles. The iron-works in the upper valley of the Mella had long created a considerable demand for wood, but their operations were not so extensive as to occasion any very sudden or general destruction of the forests, and the only evil experienced from the clearings was the gradual diminution of the volume of the river. Within the last thirty years, the superior quality of the arms manufactured at Brescia has greatly enlarged the sale of them, and very naturally stimulated the activity of both the forges and of the colliers who supply them, and the hillsides have been rapidly stripped of their timber. Up to 1850, no destructive inundation of the Mella had been recorded. Buildings in great numbers had been erected upon its margin, and its valley was conspicuous for its rural beauty and its fertility. But when the denudation of the mountains had reached a certain point, avenging nature began the work of retribution. In the spring and summer of 1850 several new torrents were suddenly formed in the upper tributary valleys, and on the 14th and 15th of August in that year a fall of rain, not heavier than had been often experienced, produced a flood which not only inundated much ground never before overflowed, but destroyed a great number of bridges, dams, factories, and other valuable structures, and, what was a far more serious evil, swept off from the rocks an incredible extent of soil, and converted one of the most beautiful valleys of the Italian Alps into a ravine almost as bare and as barren as the savagest gorge of Southern France. The pecuniary damage was estimated at many millions of francs, and the violence of the catastrophe was deemed so extraorthe fields and the deluging overflow of the raging waters, the streams are confined by walls and embankments, which are gradually built higher and higher as the bed of the torrent is raised, so that, to reach a river, you ascend from the fields beside it; and sometimes the ordinary level of the stream is above the streets and even the roofs of the towns through which it passes.*

The traveller who visits the depths of an Alpine ravine, observes the length and width of the gorge and the great height and apparent solidity of the precipitous walls which bound it, and calculates the mass of rock required to fill the vacancy, can hardly believe that the humble brooklet which purls at his feet has been the principal agent in accomplishing this tremendous erosion. Closer observation will often teach him, that the seemingly unbroken rock which overhangs the valley is full of cracks and fissures, and really in such a state

---

dinary, even in a country subject to similar visitations, that the sympathy excited for the sufferers produced, in five months, voluntary contributions for their relief to the amount of nearly $200,000.—*Delle Inondazioni del Mella, etc., nella notte del* 14 *al* 15 *Agosto*, 1850.

The author of this pamphlet has chosen as a motto a passage from the Vulgate translation of Job, which is interesting as showing accurate observation of the action of the torrent: "Mons cadens definit, et saxum transfertur de loco suo; lapides excavant aquæ et alluvione paullatim terra consumitur."—Job xiv. 18, 19.

The English version is much less striking, and gives a different sense.

The recent date of the change in the character of the Mella is contested, and it is possible that, though the extent of the revolution is not exaggerated, the rapidity with which it has taken place may have been.

* Streffleur quotes from Duile the following observations: "The channel of the Tyrolese brooks is often raised much above the valleys through which they flow. The bed of the Fersina is elevated high above the city of Trent, which lies near it. The Villerbach flows at a much more elevated level than that of the market-place of Neumarkt and Vill, and threatens to overwhelm both of them with its waters. The Talfer at Botzen is at least even with the roofs of the adjacent town, if not above them. The tower-steeples of the villages of Schlanders, Kortsch, and Laas, are lower than the surface of the Gadribach. The Saldurbach at Schluderns menaces the far lower village with destruction, and the chief town, Schwaz, is in similar danger from the Lahnbach."—STREFFLEUR, *Ueber die Wildbäche*, etc., p. 7.

of disintegration that every frost must bring down tons of it. If he compute the area of the basin which finds here its only discharge, he will perceive that a sudden thaw of the winter's deposit of snow, or one of those terrible discharges of rain so common in the Alps, must send forth a deluge mighty enough to sweep down the largest masses of gravel and of rock. The simple measurement of the cubical contents of the semicircular hillock which he climbed before he entered the gorge, the structure and composition of which conclusively show that it must have been washed out of this latter by torrential action, will often account satisfactorily for the disposal of most of the matter which once filled the ravine.

When a torrent escapes from the lateral confinement of its mountain walls and pours out of the gorge, it spreads and divides itself into numerous smaller streams which shoot out from the mouth of the ravine as from a centre, in different directions, like the ribs of a fan from the pivot, each carrying with it its quota of stones and gravel. The plain below the point of issue from the mountain is rapidly raised by newly-formed torrents, the elevation depending on the inclination of the bed and the form and weight of the matter transported. Every flood both increases the height of this central point and extends the entire circumference of the deposit.

Other things being equal, the transporting power of the water is greatest where its flow is most rapid. This is usually in the direction of the axis of the ravine. The stream retaining most nearly this direction moves with the greatest momentum, and consequently transports the solid matter with which it is charged to the greatest distance.

The untravelled reader will comprehend this the better when he is informed that the southern slope of the Alps generally rises suddenly out of the plain, with no intervening hill to break the abruptness of the transition, except those consisting of comparatively small heaps of its own débris brought down by ancient glaciers or recent torrents. The torrents do not wind down valleys gradually widening to the rivers or the sea, but leap at once from the flanks of the mountains upon the plains below. This arrangement of surfaces naturally facilitates the formation of vast deposits at their points of emergence, and the centre of the accumulation in the case of very small torrents is not unfrequently a hundred feet high, and sometimes very much more.

The deposits of the torrent which has scooped out the Nantzen Thal, a couple of miles below Brieg in the Valais, have built up a semicircular hillock, which most travellers by the Simplon route pass over without even noticing it, though it is little inferior in dimensions to the great cones of dejection described by Blanqui. The principal course of the torrent having been—I know not whether spontaneously or artificially—diverted towards the west, the eastern part of the hill has been gradually brought under cultivation, and there are many trees, fields, and houses upon it; but the larger western part is furrowed with channels diverging from the summit of the deposit at the outlet of the Nantzen Thal, which serve as the beds of the water-courses into which the torrent has divided itself. All this portion of the hillock is subject to inundation after long and heavy rain, and as I saw it in the great flood of October, 1866, almost its whole surface seemed covered with an unbroken sheet of rushing water.

The semi-conical deposit of detritus at the mouth of the Litznerthal, a lateral branch of the valley of the Adige, at the point where the torrent pours out of the gorge, is a thousand feet high and, measuring along the axis of the principal current, two and a half miles long.* The solid material of this hillock—which it is hardly an exaggeration to call a mountain, the work of a single insignificant torrent and its tributaries—including what the river which washes its base has carried off in a comparatively few years, probably surpasses the mass of the stupendous pyramid of the Matterhorn.

In valleys of ancient geological formation, which extend into the very heart of the mountains, the streams, though rapid, have often lost the true torrential character, if, indeed, they ever possessed it. Their beds have become approximately constant, and their walls no longer crumble and fall into the waters that wash their bases. The torrent-worn ravines, of which I have spoken, are of later date, and belong more properly to what may be called the crust of the Alps, consisting of loose rocks, of gravel, and of earth, strewed along the surface of the great declivities of the central ridge, and accumulated thickly between their solid buttresses. But it is on this crust that the mountaineer dwells. Here are his forests, here his pastures, and the ravages of the torrent both destroy his world, and convert it into a source of overwhelming desolation to the plains below.

---

* SONKLAR, *Die Oetzthaler Gebirgsgruppe*, 1861, p. 231.

I do not mean to assert that all the rocky valleys of the Alps have been produced by the action of torrents resulting from the destruction of the forests. The greater, and many of the smaller channels, by which that chain is drained, owe their origin to higher causes. They are primitive fissures, ascribable to disruption in upheaval or other geological convulsion, widened and scarped, and often even polished, so to speak, by the action of glaciers during the ice period, and but little changed in form by running water in later eras.

It has been contended that all rivers which take their rise in mountains originated in torrents. These, it is said, have lowered the summits by gradual erosion, and, with the material thus derived, have formed shoals in the sea which once beat against the cliffs; then, by successive deposits, gradually raised them above the surface, and finally expanded them into broad plains traversed by gently flowing streams. If we could go back to earlier geological periods, we should find this theory often verified, and we cannot fail to see that the torrents go on at the present hour, depressing still lower the ridges of the Alps and the Apennines, raising still higher the plains of Lombardy and Provence, extending the coast still farther into the Adriatic and the Mediterranean, reducing the inclination of their own beds and the rapidity of their flow, and thus tending to become river-like in character.

We cannot measure the share which human action has had in augmenting the intensity of causes of mountain degradation, and of the formation of plains and marshes below, but we know that the clearing of the woods has, in some cases, produced, within two or three generations, effects as blasting as those generally ascribed to geological convulsions, and has laid waste the face of the earth more hopelessly than if it had been buried by a current of lava or a shower of volcanic sand. New torrents are forming every year in the Alps. Tradition, written records, and analogy concur to establish the belief that the ruin of most of the now desolate valleys in those mountains is to be ascribed to the same cause, and authentic descriptions of the irresistible force of the torrent show that, aided by frost and heat, it is adequate to level Mont Blanc and Monte Rosa themselves, unless new upheavals shall maintain their elevation.

There are cases where torrents cease their ravages of themselves, in consequence of some change in the condition of the basin where they originate, or of the face of the mountain at a higher level, while the plain or the sea below remains in substantially the same state as before. If a torrent rises in a small valley containing no great amount of earth and of disintegrated or loose rock, it may, in the course of a certain period, wash out all the transportable material, and if the valley is then left with solid walls, it will cease to furnish débris to be carried down by floods. If, in this state of things, a new channel be formed at an elevation above the head of the valley, it may divert a part or even the whole of the rain-water and melted snow which would otherwise have flowed into it, and the once furious torrent now sinks to the rank of a humble and harmless brooklet. "In traversing this department," says Surell, "one often sees, at the outlet of a gorge, a flattened hillock, with a fan-shaped outline and regular slopes; it is the bed of dejection of an ancient torrent. It sometimes requires long and careful study to detect the primitive form, masked as it is by groves of trees, by cultivated fields, and often by houses, but, when examined closely, and from different points of view, its characteristic figure manifestly appears, and its true history cannot be mistaken. Along the hillock flows a streamlet, issuing from the ravine, and quietly watering the fields. This was originally a torrent, and in the background may be discovered its mountain basin. Such *extinguished* torrents, if I may use the expression, are numerous." *

But for the intervention of man and domestic animals, these latter beneficent revolutions would occur more frequently, proceed more rapidly. The new scarped mountains, the hillocks of débris, the plains elevated by sand and gravel spread over them, the shores freshly formed by fluviatile deposits, would clothe themselves with shrubs and trees, the intensity of the causes of degradation would be diminished, and nature would thus regain her ancient equilibrium. But these processes, under ordinary circumstances, demand, not years, generations, but centuries; † and man, who even now finds scarce breathing-room on this vast globe, cannot retire from the Old World to some yet undiscovered continent, and wait for the slow action of such causes to replace, by a new creation, the Eden he has wasted.

---

* SURELL, *Les Torrents des Hautes Alpes*, chap. xxiv. In such cases, the clearing of the ground, which, in consequence of a temporary diversion of the waters, or from some other cause, has become rewooded, sometimes renews the ravages of the torrent. Thus, on the left bank of the Durance, a wooded declivity had been formed by the débris brought down by torrents, which had extinguished themselves after having swept off much of the superficial strata of the mountain of Morgon. "All this district was covered with woods, which have now been thinned out and are perishing from day to day; consequently, the torrents have recommenced their devastations, and if the clearings continue, this declivity, now fertile, will be ruined, like so many others."—*Ibid.*, p. 155.

† Where a torrent has not been long in operation, and earth still remains mixed with the rocks and gravel it heaps up at its point of eruption, vegetation soon starts up and prospers, if protected from encroachment. In Provence, "several communes determined, about ten years ago, to reserve the soils thus wasted, that is, to abandon them for a certain time, to spontaneous vegetation, which was not slow in making its appearance."—BECQUEREL, *Des Climats*, p. 315.

Crushing Force of Torrents.

I must here notice a mechanical effect of the rapid flow of the torrent, which is of much importance in relation to the desolating action it exercises by covering large tracts of cultivated ground with infertile material. The torrent, as we have seen, shoots or rolls forwards, with great velocity, masses and fragments of rock, and sometimes rounded pebbles from more ancient formations. Every inch of this violent movement is accompanied with crushing concussion, or, at least, with great abrasion of the mineral material, and, as you follow it along the course of the waters which transport it, you find the stones gradually rounding off in form, and diminishing in size, until they pass successively into gravel, and, in the beds of the rivers to which the torrents convey it, sand, and lastly impalpable slime.

There are few operations of nature where the effect seems more disproportioned to the cause than in this crushing and comminution of rock in the channel of swift waters. Igneous rocks are generally so hard as to be wrought with great difficulty, and they bear the weight of enormous superstructures without yielding to the pressure; but to the torrent they are as wheat to the millstone. The streams which pour down the southern scarp of the Mediterranean Alps along the Riviera di Ponente, near Genoa, have short courses, and a brisk walk of a couple of hours or even less takes you from the sea-beach to the headspring of many of them. In their heaviest floods, they bring rounded masses of serpentine quite down to the sea, but at ordinary high water their lower course is charged only with finely divided particles of that rock. Hence, while, near their sources, their channels are filled with pebbles and angular fragments, intermixed with a little gravel, the proportions are reversed near their mouths, and, just above the points where their outlets are partially choked by the rolling shingle of the beach, their beds are composed of sand and gravel to the almost total exclusion of pebbles.

Guglielmini argued that the gravel and sand of the beds of running streams were derived from the trituration of rocks by the action of the currents, and inferred that this action was generally sufficient to reduce hard rock to sand in its passage from the source to the outlet of rivers. Frisi controverted this opinion, and maintained that river-sand was of more ancient origin, and he inferred from experiments in artificially grinding stones that the concussion, friction, and attrition of rock in the channel of running waters were inadequate to its comminution, though he admitted that these same causes might reduce silicious sand to a fine powder capable of transportation to the sea by the currents.[*] Frisi's experiments were tried upon rounded and polished river-pebbles, and prove nothing with regard to the action of torrents upon the irregular, more or less weathered, and often cracked and shattered rocks which lie loose in the ground at the head of mountain valleys. The fury of the waters and of the wind which accompanies them in the floods of the French Alpine torrents is such, that large blocks of stone are hurled out of the bed of the stream to the height of twelve or thirteen feet.[†] The impulse of masses driven with such force overthrows the most solid masonry, and their concussion cannot fail to be attended with the crushing of the rocks themselves.

The greatest depth of the basin of the Ardèche is seventy-five miles, but most of its tributaries have a much shorter course. "These affluents," says Mardigny, "hurl into the bed of the Ardèche enormous blocks of rock, which this river, in its turn, bears onwards, and grinds down, at high water, so that its current rolls only gravel at its confluence with the Rhone." *

---

[*] Frisi, *Del modo di regolare i Fiumi e i Torrenti*, pp. 4–19. See in Lombardini, *Sulle Inondazioni in Francia*, p. 87, notices of the action of currents transporting only fine material in wearing down hard rock. In the sluices for gold-washing in California having a grade of 1 to 14½, and paved with the hardest stones, the wear of the bottom is at the rate of two inches in three months.—Raymond, *Mineral Statistics*, 1870, p. 480.

[†] Surell, *Etude sur les Torrents*, pp. 31–36.

Duponchel makes the following remarkable statement: "The river Herault rises in a granitic region, but soon reaches calcareous formations, which it traverses for more than sixty kilomètres, rolling through deep and precipitous ravines, into which the torrents are constantly discharging enormous masses of pebbles belonging to the hardest rocks of the Jurassian period. These débris, continually renewed, compose, even below the exit of the gorge where the river enters into a regular channel cut in a tertiary deposit, broad beaches, prodigious accumulations of rolled pebbles, extending several kilomètres down the stream, but they diminish in size and weight so rapidly that above the mouth of the river, which is at a distance of thirty or thirty-five kilomètres from the gorge, every trace of calcareous matter has disappeared from the sands of the bottom, which are exclusively silicious." †

Similar effects of the rapid flow of water and the concussion of stones against each other in river-beds may be observed in almost every Alpine gorge which serves as the channel of a swift stream. The tremendous cleft through which the well-known Via Mala is carried receives, every year, from its own crumbling walls and from the Hinter Rhein and its mild tributaries, enormous quantities of rock, in blocks and boulders. In fact, the masses hurled into it in a single flood like those of 1868 would probably fill it up, at its narrow points, to the

---

* At Rinkenberg, on the right bank of the Vorder Rhein, in the flood of 1868, a block of stone computed to weigh nearly 9,000 cwt. was carried bodily forwards, not rolled, by a torrent, a distance of three-quarters of a mile.—Coaz, *die Hochwasser im* 1868, p. 54.

Mémoire sur les Inondations des Rivières de l'Ardèche, p. 16. "The terrific roar, the thunder of the raging torrents proceeds principally from the stones which are rolled along in the bed of the stream. This movement is attended with such powerful attrition that, in the Southern Alps, the atmosphere of valleys where the limestone contains bitumen, has, at the time of floods, the marked bituminous smell produced by rubbing pieces of such limestone together."—Wessely, *Die Oesterreichischen Alpenländer*, i., p. 113.

† *Avant-projet pour la création d'un sol fertile*, p. 20.

level of the road 400 feet above its bottom, were not the stones crushed and carried off by the force of the current. Yet below the outlet at Thusis only small rounded boulders, pebbles, and gravel, not rock, are found in the bed of the river. The Swiss glaciers bring down thousands of cubic yards of hard rock every season. Where the glacier ends in a plain or wide valley, the rocks are accumulated in a terminal moraine, but in numerous instances the water which pours from the ice-river has force enough to carry down to larger streams the masses delivered by the glacier, and there they, with other stones washed out from the earth by the current, are ground down, so that few of the affluents of the Swiss lakes deliver into them anything but fine sand and slime.

Great rivers carry no boulders to the sea, and, in fact, receive none from their tributaries. Lombardini found, twenty years ago, that the mineral matter brought down to the Po by its tributaries was, in general, comminuted to about the same degree of fineness as the sands of its bed at their points of discharge. In the case of the Trebbia, which rises high in the Apennines and empties into the Po at Piacenza, it was otherwise, that river rolling pebbles and coarse gravel into the channel of the principal stream. The banks of the other affluents—excepting some of those which discharge their waters into the great lakes—then either retained their woods, or had been so long clear of them that the torrents had removed most of the disintegrated and loose rock in their upper basins. The valley of the Trebbia had been recently cleared, and all the forces which tend to the degradation and transportation of rock were in full activity.*

Transporting Power of Water.

But the geographical effects of the action of torrents are not confined to erosion of earth and comminution of rock; for they and the rivers to which they contribute transport the débris of the mountains to lower levels and spread them out over the dry land and the bed of the sea, thus forming alluvial deposits, sometimes of a beneficial, sometimes of an injurious, character, and of vast extent.*

---

* Since the date of Lombardini's observations, many Alpine valleys have been stripped of their woods. It would be interesting to know whether any sensible change has been produced in the character or quantity of the matter transported by the rivers to the Po.—*Notice sur les Rivières de la Lombardie*, *Annales des Ponts et Chaussées*, 1847, 1er sémestre, p. 131.

A mountain rivulet swollen by rain or melted snow, when it escapes from its usual channel and floods the adjacent fields, naturally deposits pebbles and gravel upon them; but even at low water, if its course is long enough for its grinding action to have full scope, it transports the solid material with which it is charged to some larger stream, and there lets it fall in a state of minute division, and at last the spoil of the mountain is used to raise the level of the plains or carried down to the sea.

An instance that fell under my own observation, in 1857, will serve to show something of the eroding and transporting power of streams which, in these respects, fall incalculably below the torrents of the Alps. In a flood of the Ottaquechee, a small river which flows through Woodstock, Vermont, a mill-dam on that stream burst, and the sediment with which the pond was filled, estimated after careful measurement at 13,000 cubic yards, was carried down by the current. Between this dam and the slackwater of another, four miles below, the bed of the stream, which is composed of pebbles interspersed in a few places with larger stones, is about sixty-five feet wide, though, at low water, the breadth of the current is considerably less. The sand and fine gravel were smoothly and evenly distributed over the bed to a width of fifty-five or sixty feet, and, for a distance of about two miles, except at two or three intervening rapids, filled up all the interstices between the stones, covering them to the depth of nine or ten inches, so as to present a regularly formed concave channel, lined with sand, and reducing the depth of water, in some places, from five or six feet to fifteen or eighteen inches. Observing this deposit after the river had subsided and become so clear that the bottom could be seen, I supposed that the next flood would produce an extraordinary erosion of the banks and some permanent changes in the channel of the stream, in consequence of the elevation of the bed and the filling up of the spaces between the stones through which formerly much water had flowed; but no such result followed. The spring freshet of the next year entirely washed out the sand its predecessor had left, deposited some of it in ponds and still-water reaches below, carried the residue beyond the reach of observation, and left the bed of the river almost precisely in its former condition, though, of course, with the displacement of the pebbles which every flood produces in the channels of such streams. The pond, though often previously discharged by the breakage of the dam, had then been undisturbed for about twenty-five years, and its contents consisted almost entirely of sand, the rapidity of the current in floods being such that it would let fall little lighter sediment, even above an obstruction like a dam. The quantity I have mentioned evidently bears a very inconsiderable proportion to the total erosion of the stream during that period, because the wash of the banks consists chiefly of fine earth rather than of sand, and after the pond was once filled, or nearly so, even this material could no longer be deposited in it. The fact of the complete removal of the deposit I have described between the two dams in a single freshet, shows that, in spite of considerable obstruction from roughness of bed, large quantities of sand may be taken up and carried off by streams of no great rapidity of inclination; for the whole descent of the bed of the river between the two dams—a distance of four miles—is but sixty feet, or fifteen feet to the mile.*

---

* Lorentz, in an official report quoted by Marchand, says: "The felling of the woods produces torrents which cover the cultivated soil with pebbles and fragments of rock, and they do not confine their ravages to the vicinity of the mountains, and extend them into the fertile fields of Provence and other departments, to the distance of forty or fifty leagues."—*Entwaldung der Gebirge*, p. 17.

---

* In a sheet-iron siphon, 1,000 feet long, with a diameter of four inches, having the entrance 18 feet, the orifice of discharge 40 feet below the summit of the curve, employed in draining a mine in California, the force of the current

The facts which I have adduced may aid us in forming an idea of the origin and mode of transportation of the prodigious deposits at the mouth of great rivers like the Mississippi, the Nile, the Ganges, and the Hoang-Ho, the delta of which last river, composed entirely of river sediment, has a superficial extent of not less than 96,500 square miles. But we shall obtain a clearer conception of the character of this important geographical process by measuring, more in detail, the mass of earth and rock which a well-known river and its tributaries have washed from the mountains and transported to the plains or the sea, within the historic period.

The Po and its Deposits.

The current of the River Po, for a considerable distance after its volume of water is otherwise sufficient for continuous navigation, is too rapid for that purpose until near Cremona, where its velocity becomes too much reduced to transport great quantities of mineral matter, except in a state of minute division. Its southern affluents bring down from the Apennines a large quantity of fine earth from various geological formations, while its Alpine tributaries west of the Ticino are charged chiefly with rock ground down to sand or gravel. The bed of the river has been somewhat elevated by the deposits in its channel, though not by any means above the level of the adjacent plains, as has been so often represented. The dikes, which confine the current at high water, at the same time augment its velocity and compel it to carry most of its sediment to the Adriatic. It has, therefore, raised neither its own channel nor its alluvial shores, as it would have done if it had remained unconfined. But, as the surface of the water in floods is above the general level of the plains through which it flows, the Po can, at that period, receive no contributions of earth from the washing of

---

was such as to carry through the tube great quantities of sand and coarse gravel, some of the grains of which were as large as an English walnut.—RAYMOND, *Mining Statistics*, 1870, p. 602.

the fields of Lombardy, and there is no doubt that a large proportion of the sediment it now deposits at its mouth descended from the Alps in the form of rock, though reduced by the grinding action of the waters, in its passage seaward, to the condition of fine sand, and often of silt.

We know little of the history of the Po, or of the geography of the coast near the point where it enters the Adriatic, at any period more than twenty centuries before our own. Still less can we say how much of the plains of Lombardy had been formed by its action, combined with other causes, before man accelerated its levelling operations by felling the first woods on the mountains whence its waters are derived. But we know that since the Roman conquest of Northern Italy, its deposits have amounted to a quantity which, if recemented into rock, recombined into gravel, common earth, and vegetable mould, and restored to the situations where eruption or upheaval originally placed or vegetation deposited it, would fill up hundreds of deep ravines in the Alps and Apennines, change the plan and profile of their chains, and give their southern and northern faces respectively a geographical aspect very different from that they now present. Ravenna, forty miles south of the principal mouth of the Po, was built like Venice, in a lagoon, and the Adriatic still washed its walls at the commencement of the Christian era. The mud of the Po has filled up the lagoon, and Ravenna is now four miles from the sea. The town of Adria, which lies between the Po and the Adige, at the distance of some four or five miles from each, was once a harbor famous enough to have given its name to the Adriatic Sea, and it was still accessible to large vessels, if not by the open sea at least by lagoons, in the time of Augustus. The combined action of the two rivers has so advanced the coast-line that Adria is now more than fourteen miles inland, and, in other places, the deposits made within the same period by these and other neighboring streams have a width of twenty miles.

What proportion of the earth with which they are charged these rivers have borne out into deep water, during the last two thousand years, we do not know, but as they still transport enormous quantities, as the North Adriatic appears to have shoaled rapidly, and as long islands, composed in great part of fluviatile deposits, have formed opposite their mouths, it must evidently have been very great. The floods of the Po occur but once, or sometimes twice, in a year.* At other times, its waters are comparatively limpid and seem to hold no great amount of mud or fine sand in mechanical suspension; but at high water it contains a large proportion of solid matter, and, according to Lombardini, it annually transports to the shores of the Adriatic not less than 42,760,000 cubic mètres, or very nearly 55,000,000 cubic yards, which carries the coast-line out into the sea at the rate of more than 200 feet in a year.[*] The depth of the annual deposit is stated at eighteen centimètres, or rather more than seven inches, and it would cover an area of not much less than ninety square miles with a layer of that thickness. The Adige, also, brings every year to the Adriatic many million cubic yards of Alpine detritus, and the contributions of the Brenta from the same source are far from inconsiderable. The Adriatic, however, receives but a small proportion of the soil and rock washed away from the Italian slope of the Alps and the northern declivity of the Apennines by torrents. Nearly the whole of the débris thus removed from the southern face of the Alps between Monte Rosa and the sources of the Adda—a length of watershed[†] not less than one hundred and fifty miles—is arrested by the still waters of the Lakes

---

* In the earlier mediæval centuries, when the declivities of the mountains still retained a much larger proportion of their woods, the moderate annual floods of the Po were occasioned by the melting of the snows on the lower slopes, and, according to a passage of Tasso quoted by Castellani (*Dell' Influenza delle Selve*, i., p. 58, note), they took place in May. The usually more violent inundations of later ages are due to rains, the waters of which are no longer retained by a forest-soil, but conveyed at once to the rivers—and they occur almost uniformly in the autumn or late summer. Castellani, on the page just quoted, says that even so late as about 1780, the Po required a heavy rain of a week to overflow its banks, but that forty years later it was sometimes raised to full flood in a single day.

Pliny says: "The Po, which is inferior to no river in swiftness of current, is in flood about the rising of the dog-star, the snow then melting, and though so rapid in flow, it washes nothing from the soil, but leaves it increased in fertility."—*Natural History*, Book iii., 20.

The first terrible inundation of the Po in 1872 took place in May, and appears to have been occasioned by heavy rains on the southern flank of the Alps, and to have received little accession from snow. The snow on the higher Alps does not usually thaw so as to occasion floods before August, and often considerably later. The more destructive flood of October, 1872, was caused both by thaws in the high mountains and by an extraordinary fall of rain. See *River Embankments; post.*

Pliny's remark as to enrichment of the soil by the floods appears to be verified in the case of that of October, 1872, for it is found that the water has left very extensively a thick deposit of slime on the fields.

See a list of the historically known great inundations of the Po by the engineer Zuccholli in TORELLI, *Progetto di Legge per la Vendita di Beni incolti.* Roma, 1872.

---

[*] This change of coast-line cannot be ascribed to upheaval, for a comparison of the level of old buildings—as, for instance, the church of San Vitale and the tomb of Theodoric at Ravenna—with that of the sea, tends to prove a depression rather than an elevation of their foundations.

A computation by a different method makes the deposits at the mouth of the Po 2,123,000 mètres less; but as both of them omit the gravel and silt carried down at ordinary and low water, we are safe in assuming the larger quantity.

[†] Sir John F. W. Herschel (*Physical Geography*, 137, and elsewhere) spells this word *water-sched*, because he considers it a translation, or rather an adoption, of the German "Wasser-scheide, separation of the waters, not water-*shed* the slope *down which* the waters run." As a point of historical etymology, it is probable that the word in question was suggested to those who first used it by the German *Wasserscheide*; but the spelling *water-sched*, proposed by Herschel, is objectionable, both because *sch* is a combination of letters wholly unknown to modern English orthography and properly representing no sound recognized in English orthoepy, and for the still better reason that *water-shed*, in the sense of *division-of-the-waters*, has a legitimate English etymology.

The Anglo-Saxon *sceadan* meant both to separate or divide, and to shade or shelter. It is the root of the English verbs *to shed* and *to shade*, and in the former meaning is the A. S. equivalent of the German verb *scheiden*.

Shed in Old English had the meaning *to separate* or *distinguish*. It is so used in the *Owl and the Nightingale*, v. 197. Palsgrave (*Lesclarcissement*, etc., p. 717) defines *I shede*, I departe thinges asonder; and the word still means *to divide* in several English local dialects. Hence, *watershed*, the division or separation of the waters, is good English both in etymology and in spelling.

Maggiore and Como, and some smaller lacustrine reservoirs, and never reaches the sea. The Po is not continuously embanked except for the lower half of its course. Above Cremona, therefore, it spreads and deposits sediment over a wide surface, and the water withdrawn from it for irrigation at lower points, as well as its inundations in the occasional ruptures of its banks, carry over the adjacent soil a large amount of slime. [*]

If to the estimated annual deposits of the Po at its mouth, we add the earth and sand transported to the sea by the Adige, the Brenta, and other less important streams, the prodigious mass of detritus swept into Lago Maggiore by the Tosa, the Maggia, and the Ticino, into the lake of Como by the Maira and the Adda, into the lakes of Garda, Lugano, Iseo, and Idro, by their affluents,[†] and the yet vaster heaps of pebbles, gravel, and earth permanently deposited by the torrents near their points of eruption from mountain gorges, or spread over the wide plains at lower levels, we may safely assume that we have an aggregate of not less than ten times the quantity carried to the Adriatic by the Po, or 550,000,000 cubic yards of solid matter, abstracted every year from the Italian Alps and the Apennines, and removed out of their domain by the force of running water. [‡]

---

[*] The quantity of sediment deposited by the Po on the plains which border it, before the construction of the continuous dikes and in the floods which occasionally burst through them, is vast, and the consequent elevation of those plains is very considerable. I do not know that this latter point has been made a subject of special investigation, but vineyards, with the vines still attached to the elms which supported them, have been found two or three yards below the present surface at various points on the plains of Lombardy.

[†] The Po receives about four-tenths of its waters from these lakes. See LOMBARDINI, *Dei cangiamenti nella condizione del Po*, p. 29. All the sediment carried into the lakes by their tributaries is deposited in them, and the water which flows out of them is perfectly limpid. From their proximity to the Alps and the number of torrents which empty into them, they no doubt receive vastly more transported matter than is contributed to the Po by the six-tenths of its waters received from other sources.

[‡] Mengotti estimated the mass of solid matter annually "united to the waters of the Po" at 822,000,000 cubic mètres, or nearly twenty times as much

The present rate of deposit at the mouth of the Po has continued since the year 1600, the previous advance of the coast, after the year 1200, having been only one-third as rapid. The great increase of erosion and transport is ascribed by Lombardini chiefly to the destruction of the forests in the basin of that river and the valleys of its tributaries, since the beginning of the seventeenth century.[*] We have no data to show the rate of deposit in any given century before the year 1200, and it doubtless varied according to the progress of population and the consequent extension of clearing and cultivation. The transporting power of torrents is greatest soon after their formation, because at that time their points of delivery are lower, and, of course, their general slope and velocity more rapid, than after years of erosion above, and deposit below, have depressed the beds of their mountain valleys, and elevated the channels of their lower course. Their eroding action also is most powerful at the same period, both because their mechanical force is then greatest, and because the loose earth and stones of freshly cleared forest-ground are most easily removed. Many of the Alpine valleys west of the Ticino—that of the Dora Baltea, for instance—were nearly stripped of their forests in the days of the Roman Empire, others in the Middle Ages, and, of course, there must have been, at different periods before the year 1200, epochs when the erosion and transportation of solid matter from the Alps and the Apennines were at least as great as since the year 1600.

Upon the whole, we shall not greatly err if we assume that, for a period of not less than two thousand years, the walls of the basin of the Po—the Italian slope of the Alps, and the

---

as, according to Lombardini, that river delivers into the Adriatic. Castellani supposes the computation of Mengotti to fall much below the truth, and there can be no doubt that a vastly larger quantity of earth and gravel is washed down from the Alps and the Apennines than is carried to the sea.—CASTELLANI, *Dell' Immediata Influenza delle Selve sul corso delle Acque*, i., pp. 42, 43.

I have contented myself with assuming less than one-half of Mengotti's estimate.

[*] BAUMGARTEN, *An. des Ponts et Chaussées*, 1847, 1er sémestre, p. 175.

northern and north-eastern declivities of the Apennines—have annually sent down into the lakes, the plains, and the Adriatic, not less than 375,000,000 cubic yards of earth and disintegrated rock. We have, then, an aggregate of 750,000,000,000 cubic yards of such material, which, allowing to the mountain surface in question an area of 50,000,000,000 square yards, would cover the whole to the depth of fifteen yards.[*] There are very large portions of this area, where, as we know from ancient remains—roads, bridges, and the like—from other direct testimony, and from geological considerations, very little degradation has taken place within twenty centuries, and hence the quantity to be assigned to localities where the destructive causes have been most active is increased in proportion.

If this vast mass of pulverized rock and earth were restored to the localities from which it was derived, it certainly would not obliterate valleys and gorges hollowed out by great geological causes, but it would reduce the length and diminish the depth of ravines of later formation, modify the inclination of their walls, reclothe with earth many bare mountain ridges, essentially change the line of junction between plain and mountain, and carry back a long reach of the Adriatic coast many miles to the west.[†]

It is, indeed, not to be supposed that all the degradation of the mountains is due to the destruction of the forests—that the flanks of every Alpine valley in Central Europe below the snow-line were once covered with earth and green with woods, but there are not many particular cases in which we can, with certainty, or even with strong probability, affirm the contrary.

---

[*] The total superficies of the basin of the Po, down to Ponte Lagoscuro [Ferrara]—a point where it has received all its affluents—is 6,938,200 hectares, that is, 4,105,600 in mountain lands, 2,832,600 in plain lands.—Dumont, *Travaux Publics*, etc., p. 272.

These latter two quantities are equal respectively to 10,145,348, and 6,999,638 acres, or 15,852 and 10,937 square miles.

[†] I do not use these quantities as factors the value of which is precisely ascertained; nor, for the purposes of the present argument, is quantitative exactness important. I employ numerical statements simply as a means of aiding the imagination to form a general and certainly not extravagant idea of the extent of geographical revolutions which man has done much to accelerate, if not, strictly speaking, to produce.

There is an old proverb, *Dolus latet in generalibus*, and Arthur Young is not the only public economist who has warned his readers against the deceitfulness of round numbers. I think, on the contrary, that vastly more error has been produced by the affectation of precision in cases where precision is impossible.

Mountain Slides.

Terrible as are the ravages of the torrent and the river-flood, the destruction of the woods exposes human life and industry to calamities even more appalling than those which I have yet described. The slide in the Notch of the White Mountains, by which the Willey family lost their lives, is an instance of the sort I refer to, though I am not able to say that in this particular case the slip of the earth and rock was produced by the denudation of the surface. It may have been occasioned by this cause, or by the construction of the road through the Notch, the excavations for which, perhaps, cut through the natural buttresses that supported the sloping strata above.

Not to speak of the fall of earth when the roots which held it together, and the bed of leaves and mould which sheltered

---

In all the great operations of terrestrial nature, the elements are so numerous and so difficult of exact appreciation, that, until the means of scientific observation and measurement are much more perfected than they now are, we must content ourselves with general approximations. I say *terrestrial* nature, because in cosmical movements we have fewer elements to deal with, and may therefore arrive at much more rigorous proportional accuracy in determination of time and place than we can in fixing and predicting the quantities and the epochs of variable natural phenomena on the earth's surface.

Travellers are often misled by local habits in the use of what may be called representative numbers, where a definite is put for an indefinite quantity. A Greek, who wished to express the notion of a great but undetermined number, used "myriad, or ten thousand;" a Roman, "six hundred;" an Oriental, "forty," or, at present, very commonly, "fifteen thousand." Many a tourist has gravely repeated, as an ascertained fact; the vague statement of the Arabs and the monks of Mount Sinai, that the ascent from the convent of St. Catherine to the summit of Gebel Moosa counts "fifteen thousand" steps, though the difference of level is two thousand feet; and the "Forty" Thieves, the "forty" martyr-monks of the convent of El Arbain—not to it both from disintegrating frost and from sudden drenching and dissolution by heavy showers, are gone, it is easy to see that, in a climate with severe winters, the removal of the forest, and, consequently, of the soil it had contributed to form, might cause the displacement and descent of great masses of rock. The woods, the vegetable mould, and the soil beneath, protect the rocks they cover from the direct action of heat and cold, and from the expansion and contraction which accompany them. Most rocks, while covered with earth, contain a considerable quantity of water.* A fragment of rock pervaded with moisture cracks and splits, if thrown into a furnace, and

---

speak of a similar use of this numeral in more important cases—have often been understood as expressions of a known number, when in fact they mean simply *many*. The number "fifteen thousand" has found its way to Rome, and De Quincey seriously informs us, on the authority of a lady who had been at much pains to ascertain the *exact* truth, that, including closets large enough for a bed, the Vatican contains fifteen thousand rooms. Any one who has observed the vast dimensions of most of the apartments of that structure will admit that we make a very small allowance of space when we assign a square rod, sixteen and a half feet square, to each room upon the average. On an acre, there might be one hundred and sixty such rooms, including partition walls; and, to contain fifteen thousand of them, a building must cover more than nine acres, and be ten stories high, or possess other equivalent dimensions, which, as every traveller knows, many times exceeds the truth.

The value of a high standard of accuracy in scientific observation can hardly be overrated; but habits of rigorous exactness will never be formed by an investigator who allows himself to trust implicitly to the numerical precision of the results of a few experiments. The wonderful accuracy of geodetic measurements in modern times is, in general, attained by taking the mean of a great number of observations at every station, and this final precision is but the mutual balance and compensation of numerous errors.

The pretended exactness of statistical tables is too often little better than an imposture; and those founded not on direct estimation by competent observers, but on the report of persons who have no particular interest in knowing the truth, but often have a motive for distorting it, are commonly to be regarded as but vague guesses at the actual fact.

* Rock is permeable by water to a greater extent than is generally supposed. Freshly quarried marble, and even granite, as well as most other stones, are sensibly heavier, as well as softer and more easily wrought, than after they are dried and hardened by air-seasoning. Many sandstones are porous enough to serve as filters for liquids, and much of that of Upper Egypt

sometimes with a loud detonation; and it is a familiar observation that the fire, in burning over newly cleared lands, breaks up and sometimes almost pulverizes the stones. This effect is due partly to the unequal expansion of the stone, partly to the action of heat on the water it contains in its pores. The sun, suddenly let in upon rock which had been covered with moist earth for centuries, produces more or less disintegration in the same way, and the stone is also exposed to chemical influences from which it was sheltered before. But in the climate of the United States as well as of the Alps, frost is a still more powerful agent in breaking up mountain masses. The soil that protects the lime and sandstone, the slate and the granite from the influence of the sun, also prevents the water which filters into their crevices and between their strata from freezing in the hardest winters, and the moisture descends, in a liquid form, until it escapes in springs, or passes off by deep subterranean channels. But when the ridges are laid bare, the water of the autumnal rains fills the minutest pores and veins and fissures and lines of separation of the rocks, then suddenly freezes, and bursts asunder huge, and apparently solid blocks of adamantine stone.* Where the strata are inclined at a considerable angle, the freezing of a thin film of water over a large

---

and Nubia hisses audibly when thrown into water, from the escape of the air forced out of it by hydrostatic pressure and the capillary attraction of the pores for water.

Even the denser silicious stones are penetrable by fluids and the coloring matter they contain, to such an extent that agates and other forms of silex may be artificially stained through their substance. The colors of the stones cut at Oberstein are generally produced, or at least heightened, by art. This art was known to and practised by the ancient lapidaries, and it has been revived in recent times.

* Palissy had observed the action of frost in disintegrating rock, and he thus describes it, in his essay on the formation of ice: "I know that the stones of the mountains of Ardennes be harder than marble. Nevertheless, the people of that country do not quarry the said stones in winter, for that they be subject to frost; and many times the rocks have been seen to fall without being cut, by means whereof many people have been killed, when the said rocks were thawing." Palissy was ignorant of the expansion of water in freezing—in fact, he supposed that the mechanical force exerted by

interstratal area might occasion a slide that should cover miles with its ruins; and similar results might be produced by the simple hydrostatic pressure of a column of water, admitted, by the removal of the covering of earth, to flow into a crevice faster than it could escape through orifices below.

Earth or rather mountain slides, compared to which the catastrophe that buried the Willey family in New Hampshire was but a pinch of dust, have often occurred in the Swiss, Italian, and French Alps. The land-slip, which overwhelmed, and covered to the depth of seventy feet, the town of Plurs in the valley of the Maira, on the night of the 4th of September, 1618, sparing not a soul of a population of 2,430 inhabitants, is one of the most memorable of these catastrophes, and the fall of the Rossberg or Rufiberg, which destroyed the little town of Goldau in Switzerland, and 450 of its people, on the 2d of September, 1806, is almost equally celebrated. In 1771, according to Wessely, the mountain-peak Piz, near Alleghe in the province of Belluno, slipped into the bed of the Cordevole, a tributary of the Piave, destroying in its fall three hamlets and sixty lives. The rubbish filled the valley for a distance of nearly two miles, and, by damming up the waters of the Cordevole, formed a lake about three miles long, and a hundred and fifty feet deep, which still subsists, though reduced to half its original length by the wearing down of its outlet.*

The important provincial town of Veleia, near Piacenza, where many interesting antiquities have been discovered within

---

freezing-water was due to compression, not dilatation—and therefore he ascribes to thawing alone effects resulting not less from congelation.

Various forces combine to produce the stone avalanches of the higher Alps, the fall of which is one of the greatest dangers incurred by the adventurous explorers of those regions—the direct action of the sun upon the stone, the expansion of freezing-water, and the loosening of masses of rock by the thawing of the ice which supported them or held them together.

* WESSELY, *Die Oesterreichischen Alpenländer und ihre Forste*, pp. 125, 126. Wessely records several other more or less similar occurrences in the Austrian Alps. Some of them, certainly, are not to be ascribed to the removal of the woods, but in most cases they are clearly traceable to that cause. See *Revue des Eaux et Forêts* for 1869, pp. 182, 205.

a few years, was buried by a vast land-slip, probably about the time of Probus, but no historical record of the event has survived to us.

On the 14th of February, 1855, the hill of Belmonte, a little below the parish of San Stefano, in Tuscany, slid into the valley of the Tiber, which consequently flooded the village to the depth of fifty feet, and was finally drained off by a tunnel. The mass of débris is stated to have been about 3,500 feet long, 1,000 wide, and not less than 600 high.[*]

Occurrences of this sort have been so numerous in the Alps and Apennines, that almost every Italian mountain commune has its tradition, its record, or its still visible traces of a great land-slip within its own limits. The old chroniclers contain frequent notices of such calamities, and Giovanni Villani even records the destruction of fifty houses and the loss of many lives by a slide of what seems to have been a spur of the hill of San Giorgio in the city of Florence, in the year 1284.[†]

Such displacements of earth and rocky strata rise to the magnitude of geological convulsions, but they are of so rare occurrence in countries still covered by the primitive forest, so common where the mountains have been stripped of their native covering, and, in many cases, so easily explicable by the drenching of incohesive earth from rain, or the free admission of water between the strata of rocks—both of which a coating of vegetation would have prevented—that we are justified in ascribing them for the most part to the same cause as that to which the destructive effects of mountain torrents are chiefly due—the felling of the woods.[‡]

---

[*] BIANCHI, Appendix to the Italian translation of Mrs. SOMERVILLE'S *Physical Geography*, p. xxxvi.

[†] *Cronica di* GIOVANNI VILLANI, lib. vii., cap. 97. For descriptions of other slides in Italy, see same author, lib. xi., cap. 26; FANFANI, *Antologia Italiana*, parte ii., p. 95; GIULIANI, *Linguaggio vivente della Toscana*, 1865, lettera 63.

[‡] There is good reason for thinking that many of the earth and rock slides in the Alps occurred at an earlier period than the origin of the forest vegetation which, in later ages, covered the flanks of those mountains. See *Bericht*

In nearly every case of this sort the circumstances of which are known—except the rare instances attributable to earthquakes—the immediate cause of the slip has been the imbibition of water in large quantities by bare earth, or its introduction between or beneath solid strata. If water insinuates itself between the strata, it creates a sliding surface, or it may, by its expansion in freezing, separate beds of rock, which had been nearly continuous before, widely enough to allow the gravitation of the superincumbent mass to overcome the resistance afforded by inequalities of face and by friction; if it finds its way beneath hard earth or rock reposing on clay or other bedding of similar properties, it converts the supporting layer into a semi-fluid mud, which opposes no obstacle to the sliding of the strata above.

The upper part of the mountain which buried Goldau was composed of a hard but brittle conglomerate, called *nagelflue*, resting on an unctuous clay, and inclining rapidly towards the village. Much earth remained upon the rock, in irregular masses, but the woods had been felled, and the water had free access to the surface, and to the crevices which sun and frost had already produced in the rock, and, of course, to the slimy stratum beneath. The whole summer of 1806 had been very wet, and an almost incessant deluge of rain had fallen the day preceding the catastrophe, as well as on that of its occurrence. All conditions, then, were favorable to the sliding of the rock, and, in obedience to the laws of gravitation, it precipitated itself into the valley as soon as its adhesion to the earth beneath it was destroyed by the conversion of the latter into a viscous paste. The mass that fell measured between two and a half and three miles in length by one thousand feet in width, and

---

über die Untersuchung der Schweizerischen Hochgebirgswaldungen, 1862, p. 61.

Where more recent slides have been again clothed with woods, the trees, shrubs, and smaller plants which spontaneously grow upon them are usually of different species from those observed upon soil displaced at remote periods. This difference is so marked that the site of a slide can often be recognized at a great distance by the general color of the foliage of its vegetation.

its average thickness is thought to have been about a hundred feet. The highest portion of the mountain was more than three thousand feet above the village, and the momentum acquired by the rocks and earth in their descent carried huge blocks of stone far up the opposite slope of the Rigi.

The Piz, which fell into the Cordevole, rested on a steeply inclined stratum of limestone, with a thin layer of calcareous marl intervening, which, by long exposure to frost and the infiltration of water, had lost its original consistence, and become a loose and slippery mass instead of a cohesive and tenacious bed.

Protection against Avalanches.

In Switzerland and other snowy and mountainous countries, forests render a most important service by preventing the formation and fall of destructive avalanches, and in many parts of the Alps exposed to this catastrophe, the woods are protected, though too often ineffectually, by law. No forest, indeed, could arrest a large avalanche once in full motion, but the mechanical resistance afforded by the trees prevents their formation, both by obstructing the wind, which gives to the dry snow of the *Staub-Lawine*, or dust-avalanche, its first impulse, and by checking the disposition of moist snow to gather itself into what is called the *Rutsch-Lawine*, or sliding avalanche. Marchand states that, the very first winter after the felling of the trees on the higher part of a declivity between Saanen and Gsteig where the snow had never been known to slide, an avalanche formed itself in the clearing, thundered down the mountain, and overthrew and carried with it a hitherto unviolated forest to the amount of nearly a million cubic feet of timber.* Elisée Reclus informs us in his remarkable work, *La Terre*, vol. i., p. 212, that a mountain, which rises to the south of the Pyrenæan village Araguanet in the upper valley of the Neste, having been partially stripped of its woods, a formidable avalanche rushed down from a plateau above in

---

* *Entwaldung der Gebirge*, p. 41.

1846, and swept off more than 15,000 pine-trees. The path once opened down the flanks of the mountain, the evil is almost beyond remedy. The snow sometimes carries off the earth from the face of the rock, or, if the soil is left, fresh slides every winter destroy the young plantations, and the restoration of the wood becomes impossible. The track widens with every new avalanche. Dwellings and their occupants are buried in the snow, or swept away by the rushing mass, or by the furious blasts it occasions through the displacement of the air; roads and bridges are destroyed; rivers blocked up, which swell till they overflow the valley above, and then, bursting their snowy barrier, flood the fields below with all the horrors of a winter inundation.*

---

* The importance of the wood in preventing avalanches is well illustrated by the fact that, where the forest is wanting, the inhabitants of localities exposed to snow-slides often supply the place of the trees by driving stakes through the snow into the ground, and thus checking its propensity to slip. The woods themselves are sometimes thus protected against avalanches originating on slopes above them, and as a further security, small trees are cut down along the upper line of the forest, and laid against the trunks of larger trees, transversely to the path of the slide, to serve as a fence or dam to the motion of an incipient avalanche, which may by this means be arrested before it acquires a destructive velocity and force.

In the volume cited in the text, Reclus informs us that "the village and the great thermal establishment of Barèges in the Pyrenees were threatened yearly by avalanches which precipitated themselves from a height of 1,200 mètres and at an angle of 35 degrees; so that the inhabitants had been obliged to leave large spaces between the different quarters of the town for the free passage of the descending masses. Attempts have been recently made to prevent these avalanches by means similar to those employed by the Swiss mountaineers. They cut terraces three or four yards in width across the mountain slopes and supported these terraces by a row of iron piles. Wattled fences, with here and there a wall of stone, shelter the young shoots of trees, which grow up by degrees under the protection of these defences. Until natural trees are ready to arrest the snows, these artificial supports take their place and do their duty very well. The only avalanche which swept down the slope in the year 1860, when these works were completed, did not amount to 350 cubic yards, while the masses which fell before this work was undertaken contained from 75,000 to 80,000 cubic yards."—*La Terre*, vol. i., p. 233.

under artificial stimulation and protection, and finally become hardy enough to maintain an independent existence in very different circumstances from those which at present seem essential to their life.

Besides this, although the accounts of the growth of seeds, which have lain for ages in the ashy dryness of Egyptian catacombs, are to be received with great caution, or, more probably, to be rejected altogether, yet their vitality seems almost imperishable while they remain in the situations in which nature deposits them. When a forest old enough to have witnessed the mysteries of the Druids is felled, trees of other species

---

conditions upon which the life or vigorous growth of smaller organisms depends. Particular species of truffles and of mushrooms are found associated with particular trees, without being, as is popularly supposed, parasites deriving their nutriment from the dying or dead roots of those trees. The success of Rousseau's experiments seem decisive on this point, for he obtains larger crops of truffles from ground covered with young seedling oaks than from that filled with roots of old trees. See an article on Mont Ventoux, by Charles Martins, in the *Revue des Deux Mondes*, Avril, 1863, p. 626.

It ought to be much more generally known than it is, that most if not all mushrooms, even of the species reputed poisonous, may be rendered harmless and healthful as food by soaking them for two hours in acidulated or salt water. The water requires two or three spoonfuls of vinegar or two spoonfuls of gray salt to the quart, and a quart of water is enough for a pound of sliced mushrooms. After thus soaking, they are well washed in fresh water, thrown into cold water, which is raised to the boiling-point, and, after remaining half an hour, taken out and again washed. Gérard, to prove that "crumpets is wholesome," ate one hundred and seventy-five pounds of the most poisonous mushrooms thus prepared, in a single month, fed his family *ad libitum* with the same, and finally administered them, in heroic doses, to the members of a committee appointed by the Council of Health of the city of Paris. See FIGUIER, *L'Année Scientifique*, 1862, pp. 353, 384. It should be observed that the venomous principle of poisonous mushrooms is not decomposed and rendered innocent by the process described in the note. It is merely extracted by the acidulated or saline water employed for soaking the plants, and care should be taken that this water be thrown away out of the reach of mischief.

It has long been known that the Russian peasantry eat, with impunity, mushrooms of species everywhere else regarded as very poisonous. Is it not probable that the secret of rendering them harmless—which was known to Pliny, though since forgotten in Italy—is possessed by the rustic Muscovites?

spring up in its place; and when they, in their turn, fall before the axe, sometimes even as soon as they have spread their protecting shade over the surface, the germs which their predecessors had shed years, perhaps centuries before, sprout up, and in due time, if not choked by other trees belonging to a later stage in the order of natural succession, restore again the original wood. In these cases, the seeds of the new crop may have been brought by the wind, by birds, by quadrupeds, or by other causes; but, in many instances, this explanation is not probable.

When newly cleared ground is burnt over in the United States, the ashes are hardly cold before they are covered with a crop of fire-weed, *Senecio hieracifolius*, a tall, herbaceous plant, very seldom seen growing under other circumstances, and often not to be found for a distance of many miles from the clearing. Its seeds, whether the fruit of an ancient vegetation or newly sown by winds or birds, require either a quickening by a heat which raises to a certain high point the temperature of the stratum where they lie buried, or a special pabulum furnished only by the combustion of the vegetable remains that cover the ground in the woods.

Earth brought up from wells or other excavations soon produces a harvest of plants often very unlike those of the local flora, and Hayden informs us that on our great Western desert plains, "wherever the earth is broken up, the wild sun-flower (*Helianthus*) and others of the taller-growing plants, though previously unknown in the vicinity, at once spring up, almost as if spontaneous generation had taken place." *

Moritz Wagner, as quoted by Wittwer,† remarks in his description of Mount Ararat: "A singular phenomenon to which my guide drew my attention is the appearance of several plants on the earth-heaps left by the last catastrophe [an earthquake], which grow nowhere else on the mountain, and had never been observed in this region before. The seeds of these plants were probably brought by birds, and found in the loose, clayey soil remaining from the streams of mud, the conditions of growth which the other soil of the mountain refused them." This is probable enough, but it is hardly less so that the flowing mud brought them up to the influence of air and sun, from depths where a previous convulsion had buried them ages before. Seeds of small sylvan plants, too deeply buried by successive layers of forest foliage and the mould resulting from its decomposition to be reached by the plough when the trees are gone and the ground brought under cultivation, may, if a wiser posterity replants the wood which sheltered their parent stems, germinate and grow, after lying for generations in a state of suspended animation.

---

* *Geological Survey of Wyoming*, p. 455.

† *Physikalische Geographie*, p. 486.

Darwin says: "On the estate of a relation there was a large and extremely barren heath, which had never been touched by the hand of man, but several hundred acres of exactly the same nature had been enclosed twenty-five years previously and planted with Scotch fir. The change in the native vegetation of the planted part of the heath was most remarkable—more than is generally seen in passing from one quite different soil to another; not only the proportional numbers of the heath-plants were wholly changed, but *twelve species* of plants (not counting grasses and sedges) flourished in the plantation which could not be found on the heath." * Had the author informed us that these twelve plants belonged to species whose seeds enter into the nutriment of the birds which appeared with the young wood, we could easily account for their presence in the soil; but he says distinctly that the birds were of insectivorous species, and it therefore seems more probable that the seeds had been deposited when an ancient forest protected the growth of the plants which bore them, and that they sprang up to new life when a return of favorable conditions awaked them from a sleep of centuries. Darwin indeed says that the heath "had never been touched by the hand of man." Perhaps not, after it became a heath; but what evidence is there to control the general presumption that this heath was preceded by a forest, in whose shade the vegetables which dropped the seeds in question might have grown? *

---

* *Origin of Species*, American edition, p. 69.

Although, therefore, the destruction of a wood and the reclaiming of the soil to agricultural uses suppose the death of its smaller dependent flora, these revolutions do not exclude the possibility of its resurrection. In a practical view of the subject, however, we must admit that when the woodman fells a tree he sacrifices the colony of humbler growths which had vegetated under its protection. Some wood-plants are known to possess valuable medicinal properties, and experiment may show that the number of these is greater than we now suppose. Few of them, however, have any other economical value than

---

* Writers on vegetable physiology record numerous instances where seeds have grown after lying dormant for ages. The following cases are mentioned by Dr. Dwight (*Travels*, ii., pp. 438, 439).

"The lands [in Panton, Vermont], which have here been once cultivated, and again permitted to lie waste for several years, yield a rich and fine growth of hickory [*Carya porcina*]. Of this wood there is not, I believe, a single tree in any original forest within fifty miles from this spot. The native growth was here white pine, of which I did not see a single stem in a whole grove of hickory."

The hickory is a walnut, bearing a fruit too heavy to be likely to be carried fifty miles by birds, and besides, I believe it is not eaten by any bird indigenous to Vermont. We have seen, however, on a former page, that birds transport the nutmeg, which when fresh is probably as heavy as the walnut, from one island of the Indian archipelago to another.

"A field, about five miles from Northampton, on an eminence called Rail Hill, was cultivated about a century ago. The native growth here, and in all the surrounding region, was wholly oak, chestnut, etc. As the field belonged to my grandfather, I had the best opportunity of learning its history. It contained about five acres, in the form of an irregular parallelogram. As the savages rendered the cultivation dangerous, it was given up. On this ground there sprang up a grove of white pines covering the field and retaining its figure exactly. So far as I remember, there was not in it a single oak or chestnut tree. . . . There was not a single pine whose seeds were, or, probably, had for ages been, sufficiently near to have been planted on this spot. The fact that these white pines covered this field exactly, so as to preserve both its extent and its figure, and that there were none in the neighborhood, are decisive proofs that cultivation brought up the seeds of a former forest within the limits of vegetation, and gave them an opportunity to germinate."

See, on the Succession of the Forest, THOREAU, *Excursions*, p. 135 *et seqq*.

that of furnishing a slender pasturage to cattle allowed to roam in the woods; and even this small advantage is far more than compensated by the mischief done to the young trees by browsing animals. Upon the whole, the importance of this class of vegetables, as physic or as food, is not such as to furnish a very telling popular argument for the conservation of the forest as a necessary means of their perpetuation. More potent remedial agents may supply their place in the *materia medica*, and an acre of grass-land yields more nutriment for cattle than a range of a hundred acres of forest. But he whose sympathies with nature have taught him to feel that there is a fellowship between all God's creatures; to love the brilliant ore better than the dull ingot, iodic silver and crystallized red copper better than the shillings and the pennies forged from them by the coiner's cunning; a venerable oak-tree than the brandy-cask whose staves are split out from its heart-wood; a bed of anemones, hepaticas, or wood violets than the leeks and onions which he may grow on the soil they have enriched and in the air they made fragrant—he who has enjoyed that special training of the heart and intellect which can be acquired only in the unviolated sanctuaries of nature, "where man is distant, but God is near"—will not rashly assert his right to extirpate a tribe of harmless vegetables, barely because their products neither tickle his palate nor fill his pocket; and his regret at the dwindling area of the forest solitude will be augmented by the reflection that the nurselings of the woodland perish with the pines, the oaks, and the beeches that sheltered them.*

Although, as I have said in a former chapter, birds do not frequent the deeper recesses of the wood, yet a very large proportion of them build their nests in trees, and find in their foliage and branches a secure retreat from the inclemencies of the seasons and the pursuit of the reptiles and quadrupeds which prey upon them. The borders of the forests are vocal with song; and when the gray and dewy morning calls the creeping things of the earth out of their night-cells, it summons from the neighboring wood legions of their winged enemies, which swoop down upon the fields to save man's harvests by devouring the destroying worm, and surprising the lagging beetle in his tardy retreat to the dark cover where he lurks through the hours of daylight.

---

* Quaint old Valvasor had observed the subduing influence of nature's solitudes. In describing the lonely Canker-Thal, which, though rocky, was in his time well wooded with "fir, larches, beeches and other trees," he says: "Gladsomeness and beauty, which dwell in many valleys, may not be looked for there. The journey through it is cheerless, melancholy, wearisome, and serveth to temper and mortify over-joyousness of thought. . . . In sum it is a very desert, wherein the wildness of human pride doth grow tame."—*Ehre der Crain*, i., p. 136, b.

The insects most injurious to the rural industry of the garden and the ploughland do not multiply in or near the woods. The locust, which ravages the East with its voracious armies, is bred in vast open plains which admit the full heat of the sun to hasten the hatching of the eggs, gather no moisture to destroy them, and harbor no bird to feed upon the larvæ.* It is only since the felling of the forests of Asia Minor and Cyrene that the locust has become so fearfully destructive in those countries; and the grasshopper, which now threatens to be almost as great a pest to the agriculture of some North American soils, breeds in seriously injurious numbers only where a wide extent of surface is bare of woods.

General Functions of Forests.

In the preceding pages we have seen that the electrical and chemical action of the forest, though obscure, exercises probably a beneficial, certainly not an injurious, influence on the composition and condition of the atmosphere; that it serves as a protection against the diffusion of miasmatic exhalations and malarious poisons; that it performs a most important function as a mechanical shelter from blasting winds to grounds and crops in the lee of it; that, as a conductor of heat, it tends to equalize the temperature of the earth and the air; that its dead products form a mantle over the surface, which protects the earth from excessive heat and cold; that the evaporation from the leaves of living trees, while it cools the air around them, diffuses through the atmosphere a medium which resists the escape of warmth from the earth by radiation, and hence that its general effect is to equilibrate caloric influences and moderate extremes of temperature.

---

* Smela, in the government of Kiew, has, for some years, not suffered at all from the locusts, which formerly came every year in vast swarms, and the curculio, so injurious to the turnip crops, is less destructive there than in other parts of the province. This improvement is owing partly to the more thorough cultivation of the soil, partly to the groves which are interspersed among the ploughlands. . . . When in the midst of the plains woods shall be planted and filled with insectivorous birds, the locusts will cease to be a plague and a terror to the farmer.—RENTZSCH, *Der Wald*, pp. 45, 46.

We have seen, further, that the forest is equally useful as a regulator of terrestrial and of atmospheric humidity, preventing by its shade the drying up of the surface by parching winds and the scorching rays of the sun, intercepting a part of the precipitation, and pouring out a vast quantity of aqueous vapor into the atmosphere; that if it does not increase the amount of rain, it tends to equalize its distribution both in time and in place; that it preserves a hygrometric equilibrium in the superior strata of the earth's surface; that it maintains and regulates the flow of springs and rivulets; that it checks the superficial discharge of the waters of precipitation and consequently tends to prevent the sudden rise of rivers, the violence of floods, the formation of destructive torrents, and the abrasion of the surface by the action of running water; that it impedes the fall of avalanches and of rocks, and destructive slides of the superficial strata of mountains; that it is a safeguard against the breeding of locusts, and finally that it furnishes nutriment and shelter to many tribes of animal and of vegetable life which, if not necessary to man's existence, are conducive to his rational enjoyment. In fine, in well-wooded regions, and in inhabited countries where a due proportion of soil is devoted to the growth of judiciously distributed forests, natural destructive tendencies of all sorts are arrested or compensated, and man, bird, beast, fish, and vegetable alike find a constant uniformity of condition most favorable to the regular and harmonious coexistence of them all.

General Consequences of the Destruction of the Forest.

With the extirpation of the forest, all is changed. At one season, the earth parts with its warmth by radiation to an open sky—receives, at another, an immoderate heat from the unobstructed rays of the sun. Hence the climate becomes excessive, and the soil is alternately parched by the fervors of summer, and seared by the rigors of winter. Bleak winds sweep unresisted over its surface, drift away the snow that sheltered it from the frost, and dry up its scanty moisture. The precipitation becomes as irregular as the temperature; the melting snows and vernal rains, no longer absorbed by a loose and bibulous vegetable mould, rush over the frozen surface, and pour down the valleys seawards, instead of filling a retentive bed of absorbent earth, and storing up a supply of moisture to feed perennial springs. The soil is bared of its covering of leaves, broken and loosened by the plough, deprived of the fibrous rootlets which held it together, dried and pulverized by sun and wind, and at last exhausted by new combinations. The face of the earth is no longer a sponge, but a dust-heap, and the floods which the waters of the sky pour over it hurry swiftly along its slopes, carrying in suspension vast quantities of earthy particles which increase the abrading power and mechanical force of the current, and, augmented by the sand and gravel of falling banks, fill the beds of the streams, divert them into new channels, and obstruct their outlets. The rivulets, wanting their former regularity of supply and deprived of the protecting shade of the woods, are heated, evaporated, and thus reduced in their summer currents, but swollen to raging torrents in autumn and in spring. From these causes, there is a constant degradation of the uplands, and a consequent elevation of the beds of water-courses and of lakes by the deposition of the mineral and vegetable matter carried down by the waters. The channels of great rivers become unnavigable, their estuaries are choked up, and harbors which once sheltered large navies are shoaled by dangerous sand-bars. The earth, stripped of its vegetable glebe, grows less and less productive, and, consequently, less able to protect itself by weaving a new network of roots to bind its particles together, a new carpeting of turf to shield it from wind and sun and scouring rain. Gradually it becomes altogether barren. The washing of the soil from the mountains leaves bare ridges of sterile rock, and the rich organic mould which covered them, now swept down into the dank low grounds, promotes a luxuriance of aquatic vegetation that breeds fever, and more insidious forms of mortal disease, by its decay, and thus the earth is rendered no longer fit for the habitation of man.*

To the general truth of this sad picture there are many exceptions, even in countries of excessive climates. Some of these are due to favorable conditions of surface, of geological structure, and of the distribution of rain; in many others, the evil consequences of man's improvidence have not yet been experienced, only because a sufficient time has not elapsed, since the felling of the forest, to allow them to develop themselves. But the vengeance of nature for the violation of her harmonies, though slow, is sure, and the gradual deterioration of soil and climate in such exceptional regions is as certain to result from the destruction of the woods as is any natural effect to follow its cause.

Due Proportion of Woodland.

The proportion of woodland that ought to be permanently maintained for its geographical and atmospheric influences varies according to the character of soil, surface, and climate.

---

* Almost every narrative of travel in those countries which were the earliest seats of civilization, contains evidence of the truth of these general statements, and this evidence is presented with more or less detail in most of the special works on the forest which I have occasion to cite. I may refer particularly to HOHENSTEIN, *Der Wald*, 1860, as full of important facts on this subject. See also CAIMI, *Cenni sulla Importanza dei Boschi*, for some statistics, not readily found elsewhere, on this and other topics connected with the forest.

In countries with a humid sky, or moderately undulating surface and an equable temperature, a small extent of forest, enough to serve as a mechanical screen against the action of the wind in localities where such protection is needed, suffices. But most of the territory occupied by civilized man is exposed, by the character of its surface and its climate, to a physical degradation which cannot be averted except by devoting a large amount of soil to the growth of the woods.

From an economical point of view, the question of the due proportion of forest is not less complicated or less important than in its purely physical aspects. Of all the raw materials which nature supplies for elaboration by human art, wood is undoubtedly the most useful, and at the same time the most indispensable to social progress.*

The demand for wood, and of course the quantity of forest required to furnish it, depend upon the supply of fuel from other sources, such as peat and coal, upon the extent to which stone, brick, or metal can advantageously be substituted for wood in building, upon the development of arts and industries employing wood and other forest products as materials, and upon the cost of obtaining them from other countries, or upon their commercial value as articles of export.

---

* In an imaginary dialogue in the *Recepte Vèritable*, the author, Palissy, having expressed his indignation at the folly of men in destroying the woods, his interlocutor defends the policy of felling them, by citing the example of "divers bishops, cardinals, priors, abbots, monkeries and chapters, which, by cutting their woods, have made three profits," the sale of the timber, the rent of the ground, and the "good portion" they received of the grain grown by the peasants upon it. To this argument Palissy replies: "I cannot enough detest this thing, and I call it not an error, but a curse and a calamity to all France; for when forests shall be cut, all arts shall cease, and they which practise them shall be driven out to eat grass with Nebuchadnezzar and the beasts of the field. I have divers times thought to set down in writing the arts which shall perish when there shall be no more wood; but when I had written down a great number, I did perceive that there could be no end of my writing, and having diligently considered, I found there was not any which could be followed without wood." . . "And truly I could well allege to thee a thousand reasons, but 'tis so cheap a philosophy, that the very chamber-wenches, if they do but think, may see that without wood, it is not possible to exercise any manner of human art or cunning."—*Œuvres de* BERNARD PALISSY. Paris, 1844, p. 89.

Upon the whole, taking civilized Europe and America together, it is probable that from twenty to twenty-five per cent. of well-wooded surface is indispensable for the maintenance of normal physical conditions, and for the supply of materials so essential to every branch of human industry and every form of social life as those which compose the harvest of the woods.

There is probably no country—there are few large farms even—where at least one-fourth of the soil is not either unfit for agricultural use, or so unproductive that, as pasture or as ploughland, it yields less pecuniary return than a thrifty wood. Every prairie has its sloughs where willows and poplars would find a fitting soil, every Eastern farm its rocky nooks and its barren hillsides suited to the growth of some species from our rich forest flora, and everywhere belts of trees might advantageously be planted along the roadsides and the boundaries and dividing fences. In most cases, it will be found that trees may be made to grow well where cultivated crops will not repay the outlay of tillage, and it is a very plain dictate of sound economy that if trees produce a better profit than the same ground would return if devoted to grass or grain, the wood should be substituted for the field.

Woodland in European Countries.

In 1862, Rentzsch calculated the proportions of woodland in different European countries as follows: *

Norway	66	per cent.
Sweden	60	"
Russia	30.90	"
Germany	26.58	"
Belgium	18.52	"
France	16.79	"
Switzerland	15	"

---

* *Der Wald*, pp. 123, 124.

Sardinia	12.29	per cent.
Neapolitan States	9.43	"
Holland	7.10	"
Spain	5.52	"
Denmark	5.50	"
Great Britain	5	"
Portugal	4.40	"

The large proportion of woodland in Norway and Sweden is in a great measure to be ascribed to the mountainous character of the surface, which renders the construction of roads difficult and expensive, and hence the forests are comparatively inaccessible, and transportation is too costly to tempt the inhabitants to sacrifice their woods for the sake of supplying distant markets.

The industries which employ wood as a material have only lately been much developed in these countries, and though the climate requires the consumption of much wood as a fuel, the population is not numerous enough to create, for this purpose, a demand exceeding the annually produced supply, or to need any great extension of cleared ground for agricultural purposes. Besides this, in many places peat is generally employed as domestic fuel. Hence, though Norway has long exported a considerable quantity of lumber,* and the iron and copper works of Sweden consume charcoal very largely, the forests have not diminished rapidly enough to produce very sensible climatic or even economical evils.

At the opposite end of the scale we find Holland, Denmark, Great Britain, Spain, and Portugal. In the three first-named countries a cold and humid climate renders the almost constant maintenance of domestic fires a necessity, while in Great

---

* Railway-ties, or, as they are called in England, *sleepers*, are largely exported from Norway to India, and sold at Calcutta at a lower price than timber of equal quality can be obtained from the native woods.—*Reports on Forest Conservancy*, vol. i., pt. ii., p. 1533.

From 1861 to 1870 Norway exported annually, on the average, more than 60,000,000 cubic feet of lumber.—WULFSBERG, *Norges Velstandskilder*. Christiania, 1872.

Britain especially the demand of the various industries which depend on wood as a material, or on mechanical power derived from heat, are very great. Coal and peat serve as a combustible instead of wood in them all, and England imports an immense quantity of timber from her foreign possessions. Fortunately, the character of soil, surface, and climate renders the forest of less importance as a geographical agent in these northern regions than in Spain and Portugal, where all physical conditions concur to make a large extent of forest an almost indispensable means of industrial progress and social advancement.

Rentzsch, in fact, ascribes the political decadence of Spain almost wholly to the destruction of the forest. "Spain," observes he, "seemed destined by her position to hold dominion over the world, and this in fact she once possessed. But she has lost her political ascendancy, because, during the feeble administration of the successors of Philip II., her exhausted treasury could not furnish the means of creating new fleets, the destruction of the woods having raised the price of timber above the means of the state."* On the other hand, the same writer argues that the wealth and prosperity of modern England are in great part due to the supply of lumber, as well as of other material for ship-building, which she imports from her colonies and other countries with which she maintains commercial relations.

---

* *Der Wald*, p. 63. Antonio Ponz (*Viage de España*, i., prólogo, p. lxiii.), says: "Nor would this be so great an evil, were not some of them declaimers against *trees*, thereby proclaiming themselves, in some sort, enemies of the works of God, who gave us the leafy abode of Paradise to dwell in, where we should be even now sojourning, but for the first sin, which expelled us from it."

I do not know at what period the two Castiles were bared of their woods, but the Spaniard's proverbial "hatred of a tree" is of long standing. Herrera combats this foolish prejudice; and Ponz, in the prologue to the ninth volume of his journey, says that many carried it so far as wantonly to destroy the shade and ornamental trees planted by the municipal authorities. "Trees," they contended, and still believe, "breed birds, and birds eat up the grain." Our author argues against the supposition of the "breeding of birds by trees," which, he says, is as absurd as to believe that an elm-tree can yield pears; and he charitably suggests that the expression is, perhaps, a *manière de dire*, a popular phrase, signifying simply that trees harbor birds.

Forests of Great Britain.

The proportion of forest is very small in Great Britain, where, as I have said, on the one hand, a prodigious industrial activity requires a vast supply of ligneous material, but where, on the other, the abundance of coal, which furnishes a sufficiency of fuel, the facility of importation of timber from abroad, and the conditions of climate and surface combine to reduce the necessary quantity of woodland to its lowest expression.

With the exception of Russia, Denmark, and parts of Germany, no European countries can so well dispense with the forests, in their capacity of conservative influences, as England and Ireland. Their insular position and latitude secure an abundance of atmospheric moisture; the general inclination of surface is not such as to expose it to special injury from torrents, and it is probable that the most important climatic action exercised by the forest in these portions of the British empire, is in its character of a mechanical screen against the effects of wind. The due proportion of woodland in England and Ireland is, therefore, a question not of geographical, but almost purely of economical, expediency, to be decided by the comparative direct pecuniary return from forest-growth, pasturage, and ploughland.

Contrivances for economizing fuel came later into use in the British Islands than on the Continent. Before the introduction of a system of drainage, the soil, like the sky, was, in general, charged with humidity; its natural condition was unfavorable for the construction and maintenance of substantial common roads, and the transportation of so heavy a material as coal, by land, from the remote counties where alone it was mined in the Middle Ages, was costly and difficult. For all these reasons, the consumption of wood was large, and apprehensions of the exhaustion of the forests were excited at an early period. Legislation there, as elsewhere, proved ineffectual to protect them, and many authors of the sixteenth century express fears of serious evils from the wasteful economy of the people in this respect. Harrison, in his curious chapter "Of Woods and Marishes" in Holinshed's compilation, complains of the rapid decrease of the forests, and adds: "Howbeit thus much I dare affirme, that if woods go so fast to decaie in the next hundred yeere of Grace, as they haue doone and are like to doo in this, . . . it is to be feared that the fennie bote, broome, turfe, gall, heath, firze, brakes, whinnes, ling, dies, hassacks, flags, straw, sedge, réed, rush, and also *seacole*, will be good merchandize euen in the citie of London, whereunto some of them euen now haue gotten readie passage, and taken vp their innes in the greatest merchants' parlours. . . . I would wish that I might liue no longer than to sée foure things in this land reformed, that is: the want of discipline in the church: the couetous dealing of most of our merchants in the preferment of the commodities of other countries, and hinderance of their owne: the holding of faires and markets vpon the sundaie to be abolished and referred to the wednesdaies: and that euerie man, in whatsoeuer part of the champaine soile enioieth fortie acres of land, and vpwards, after that rate, either by frée deed, copie hold, or fee farme, might plant one acre of wood, or sowe the same with oke mast, hasell, béech, and sufficient prouision be made that it may be cherished and kept. But I feare me that I should then liue too long, and so long, that I should either be wearie of the world, or the world of me."[*]

---

[*] HOLINSHED, reprint of 1807, i., pp. 357, 358. It is evident from this passage, and from another on page 397 of the same volume, that, though sea-coal was largely exported to the Continent, it had not yet come into general use in England. It is a question of much interest, when mineral coal was first employed in England for fuel. I can find no evidence that it was used as a combustible until more than a century after the Norman conquest. It has been said that it was known to the Anglo-Saxon population, but I am acquainted with no passage in the literature of that people which proves this. The dictionaries explain the Anglo-Saxon word *græfa* by sea-coal. I have met with this word in no Anglo-Saxon work, except in the *Chronicle*, A.D. 852,

Evelyn's "Silva," the first edition of which appeared in 1664, rendered an extremely important service to the cause of the woods, and there is no doubt that the ornamental plantations in which England far surpasses all other countries, are, in some measure, the fruit of Evelyn's enthusiasm. In England, how-

---

from a manuscript certainly not older than the 12th century, and in two citations from Anglo-Saxon charters, one published by Kemble in *Codex Diplomaticus*, the other by Thorpe in *Diplomatarium Anglicum*, in all which passages it more probably means peat than mineral coal. According to Way, *Promptorium Parvulorum*, p. 506, *note*, the *Catholicon Anglicanum* has "A turfe grafte, *turbarium*." *Grafte* is here evidently the same word as the A.-S. *græfa*, and the Danish *Törvegraf*, a turf-pit, confirms this opinion. Coal is not mentioned in King Alfred's Bede, in Neckam, in Glanville or in Robert of Gloucester, though the two latter writers speak of the allied mineral, jet, and are very full in their enumeration of the mineral productions of the island.

In a Latin poem ascribed to Giraldus Cambrensis, who died after the year 1220, but found also in the manuscripts of Walter Mapes (see Camden Society edition, pp. 131 and 350), and introduced into Higden's Polychronicon (London, 1865, pp. 398, 399), *carbo sub terra cortice*, which can mean nothing but pit-coal, is enumerated among the natural commodities of England. Some of the translations of the 13th and 14th century render *carbo* by *cool* or *col*, some by *gold*, and some omit this line, as well as others unintelligible to the translators. Hence, although Giraldus was acquainted with coal, it certainly was not generally known to English writers until at least a century after the time of that author.

The earliest mediæval notice of mineral coal I have met with is in a passage cited by Ducange from a document of the year 1198, and it is an etymological observation of some interest, that *carbones ferrei*, as sea-coal is called in the document, are said by Ducange to have been known in France by the popular name of *hulla*, a word evidently identical with the modern French *houille* and the Cornish *Hued*, which in the form *wheal* is an element in the name of many mining localities.

England was anciently remarkable for its forests, but Cæsar says it wanted the *fagus* and the *abies*. There can be no doubt that *fagus* means the beech, which, as the remains in the Danish peat-mosses show, is a tree of late introduction into Denmark, where it succeeded the fir, a tree not now native to that country. The succession of forest crops seems to have been the same in England; for Harrison, p. 359, speaks of the "great store of firre" found lying "at their whole lengths" in the "fens and marises" of Lancashire and other counties, where not even bushes grew in his time. We cannot be sure what species of evergreen Cæsar intended by *abies*. The popular designations of spike-leaved trees are always more vague and uncertain in their application ever, arboriculture, the planting and nursing of single trees, has, until comparatively recent times, been better understood than sylviculture, the sowing and training of the forest. But this latter branch of rural improvement now receives great attention from private individuals, though, so far as I know, not from the

---

than those of broad-leaved trees. *Pinus, pine,* has been very loosely employed even in botanical nomenclature, and *Kiefer, Fichte,* and *Tanne* are often confounded in German.—ROSSMÄSSLER, *Der Wald,* pp. 256, 289, 324. A similar confusion in the names of this family of trees exists in India. Dr. Cleghorn, Inspector-General of the Indian Forests, informs us in his official Circular No. 2, that the name of *deodar* is applied in some provinces to a cypress, in some to a cedar, and in others to a juniper. If it were certain that the *abies* of Cæsar was the fir formerly and still found in peat-mosses, and that he was right in denying the existence of the beech in England in his time, the observation would be very important, because it would fix a date at which the fir had become extinct, and the beech had not yet appeared in the island.

The English oak, though strong and durable, was not considered generally suitable for finer work in the sixteenth century. There were, however, exceptions. "Of all in Essex," observes HARRISON, *Holinshed,* i., p. 357, "that growing in Bardfield parke is the finest for ioiners craft: for oftentimes haue I seene of their workes made of that oke so fine and faire, as most of the wainescot that is brought hither out of Danske [Danzig]; for our wainescot is not made in England. Yet diuerse haue assaied to deale with our okes to that end, but not with so good successe as they haue hoped, bicause the ab or iuice will not so soone be remoued and cleane drawne out, which some attribute to want of time in the salt water."

This passage is also of interest as showing that soaking in salt-water, as a mode of seasoning, was practised in Harrison's time.

But the importation of wainscot, or boards for ceiling, panelling, and otherwise finishing rooms, which was generally of oak, commenced at least three centuries before the time of Harrison. On page 204 of the *Liber Albus* mention is made of "squared oak timber," brought in from the country by carts, and of course of domestic growth, as free of city duty or octroi, and of "planks of oak" coming in in the same way as paying one plank a cart-load. But in the chapter on the "Customs of Billyngesgate," pp. 208, 209, relating to goods imported from foreign countries, an import duty of one halfpenny is imposed on every hundred of boards called "weynscotte"—a term formerly applied only to oak—and of one penny on every hundred of boards called "Rygholt." The editor explains "Rygholt" as "wood of Riga." This was doubtless pine or fir. The year in which these provisions were made does not appear, but they belong to the reign of Henry III.

National Government, except in the East Indian provinces, where the forestal department has assumed great importance.*

In fact, England is, I believe, the only European country where private enterprise has pursued sylviculture on a really great scale, though admirable examples have been set in many others. In England the law of primogeniture, and other institutions and national customs which tend to keep large estates long undivided and in the same line of inheritance, the wealth of the landholders, the special adaptation of the climate to the growth of forest-trees, and the difficulty of finding safe and profitable investments of capital, combine to afford encouragements for the plantation of forests, which scarcely exist elsewhere in the same degree.

In Scotland, where the country is for the most part broken and mountainous, the general destruction of the forests has been attended with very serious evils, and it is in Scotland that many of the most extensive British forest plantations have now been formed. But although the inclination of surface in Scotland is rapid, the geological constitution of the soil is not of a character to promote such destructive degradation by running water as in Southern France, and it has not to contend with the parching droughts by which the devastations of the torrents are rendered more injurious in those provinces.

It is difficult to understand how either law or public opinion, in a country occupied by a dense and intelligent population, and, comparatively speaking, with an infertile soil, can tolerate the continued withdrawal of a great portion of the territory from the cultivation of trees and from other kinds of rural economy, merely to allow wealthy individuals to amuse themselves with field-sports. In Scotland, 2,000,000 acres, as well suited to the growth of forests and for pasture as is the soil generally, are withheld from agriculture, that they may be given up to herds of deer protected by the game laws. A single nobleman, for example, thus appropriates for his own pleasures not less than 100,000 acres.* In this way one-tenth of all the land of Scotland is rendered valueless in an economical point of view—for the returns from the sale of the venison and other game scarcely suffice to pay the game-keepers and other incidental expenses—and in these so-called *forests* there grows neither building timber nor fire-wood worth the cutting, as the animals destroy the young shoots.

---

* The improvidence of the population under the native and early foreign governments has produced great devastations in the forests of the British East Indian provinces, and the demands of the railways for fuel and timber have greatly augmented the consumption of lumber, and of course contributed to the destruction of the woods. The forests of British India are now, and for several years have been, under the control of an efficient governmental organization, with great advantage both to the government and to the general private interests of the people.

The official Reports on Forest Conservancy from May, 1862, to August, 1871, in 4 vols. folio, contain much statistical and practical information on all subjects connected with the administration of the forest.

Forests of France.

The preservation of the woods was one of the wise measures recommended to France by Sully, in the time of Henry IV., but the advice was little heeded, and the destruction of the forests went on with such alarming rapidity, that, two generations later, Colbert uttered the prediction: "France will perish for want of wood." Still, the extent of wooded soil was very great, and the evils attending its diminution were not so sensibly felt, that either the government or public opinion saw the necessity of authoritative interference, and in 1750 Mirabeau estimated the remaining forests of the kingdom at seventeen millions of hectares [42,000,000 acres]. In 1860 they were reduced to eight millions [19,769,000 acres], or at the rate of 82,000 hectares [202,600 acres] per year. Troy, from whose valuable pamphlet, *Étude sur le Reboisement des Montagnes*, I take these statistical details, supposes that Mirabeau's statement may have been an extravagant one, but it still remains certain that the waste has been enormous; for it is known that, in some departments, that of Ariège, for instance, clearing has gone on during the last half-century at the rate of three thousand acres a year, and in all parts of the empire trees have been felled faster than they have grown.[*] The total area of France in Mirabeau's time, excluding Savoy, but including Alsace and Lorraine, was about one hundred and thirty-one millions of acres. The extent of forest supposed by Mirabeau would be about thirty-two per cent. of the whole territory. In a country and a climate where the conservative influences of the forest are so necessary as in France, trees must cover a large surface and be grouped in large masses, in order to discharge to the best advantage the various functions assigned to them by nature. The consumption of wood is rapidly increasing in that empire, and a large part of its territory is mountainous, sterile, and otherwise such in character or situation that it can be more profitably devoted to the growth of wood than to any agricultural use. Hence it is evident that the proportion of forest in 1750, taking even Mirabeau's large estimate, was not very much too great for permanent maintenance, though doubtless the distribution was so unequal that it would have been sound policy to fell the woods and clear land in some provinces, while large forests should have been planted in others.* During the period in question France neither exported manufactured wood or rough timber, nor derived important collateral advantages of any sort from the destruction of her forests. She is consequently impoverished and crippled to the extent of the difference between what she actually possesses of wooded surface and what she ought to have retained.†

---

* ROBERTSON, *Our Deer Forests.* London, 1867.

---

[*] Among the indirect proofs of the comparatively recent existence of extensive forests in France, may be mentioned the fact that wolves were abundant, not very long since, in parts of the empire where there are now neither wolves nor woods to shelter them. Arthur Young more than once speaks of the "innumerable multitudes" of these animals which infested France in 1789, and George Sand states, in the *Histoire de ma Vie*, that some years after the restoration of the Bourbons, they chased travellers on horseback in the southern provinces, and literally knocked at the doors of her father-in-law's country seat. Eugénie de Guérin, writing from Rayssac in Languedoc in 1831 speaks of hearing the wolves fighting with dogs in the night under her very windows. *Lettres*, 2d ed., p. 6.

There seems to have been a tendency to excessive clearing in Central and Western, earlier than in South-eastern, France. Bernard Palissy, in the *Recepte Véritable*, first printed in 1563, thus complains: "When I consider the value of the least clump of trees, or even of thorns, I much marvel at the great ignorance of men, who, as it seemeth, do nowadays study only to break down, fell, and waste the fair forests which their forefathers did guard so choicely. I would think no evil of them for cutting down the woods, did they but replant again some part of them; but they care nought for the time to come, neither reck they of the great damage they do to their children which shall come after them."—*Œuvres Complètes de* BERNARD PALISSY, 1844, p. 88.

The force of the various considerations which have been suggested in regard to the importance of the forest has been generally felt in France, and the subject has been amply debated in special treatises, in scientific journals, and by the public press, as well as in the legislative body of that country. Perhaps no one point has been more prominent in the discussions than the influence of the forest in equalizing and regulating the flow of the water of precipitation. Opinion is still sómewhat divided on this subject, but the value of the woods as a safeguard against the ravages of torrents is universally acknowledged, and it is hardly disputed that the rise of river-floods is, even if as great, at least less sudden in streams having their sources in well-wooded territory.

---

* The view I have taken of this point is confirmed by the careful investigations of Rentzsch, who estimates the proper proportion of woodland to entire surface at twenty-three per cent. for the interior of Germany, and supposes that near the coast, where the air is supplied with humidity by evaporation from the sea, it might safely be reduced to twenty per cent. See Rentzsch's very valuable prize essay, *Der Wald im Haushalt der Natur und der Volkswirthschaft*, cap. viii.

The due proportion in France would considerably exceed that for the German States, because France has relatively more surface unfit for any growth but that of wood, because the form and geological character of her mountains expose her territory to much greater injury from torrents, and because at least her southern provinces are more frequently visited both by extreme droughts and by deluging rains.

† In 1863, France imported lumber to the value of twenty-five and a half millions of dollars, and exported to the amount of six and a half millions of dollars. The annual consumption of France was estimated in 1866 at 212,000,000 cubic feet for building and manufacturing, and 1,588,500,000 for firewood and charcoal. The annual product of the forest-soil of France does not exceed 70,000,000 cubic feet of wood fit for industrial use, and 1,300,000,000 cubic feet consumed as fuel. This estimate does not include the product of scattered trees on private grounds, but the consumption is estimated to exceed the production of the forests by the amount of about twenty millions of dollars. It is worth noticing that the timber for building and manufacturing produced in France comes almost wholly from the forests of the state or of the communes.—JULES CLAVÉ, in *Revue des Deux Mondes* for March 1, 1866, p. 207.

Upon the whole, the conservative action of the woods in regard to torrents and to inundations has been generally recognized by the public of France as a matter of prime importance, and the Government of the empire has made this principle the basis of a special system of legislation for the protection of existing forests, and for the formation of new. The clearing of woodland, and the organization and functions of a police for its protection, are regulated by a law bearing date June 18th, 1859, and provision was made for promoting the restoration of private woods by a statute adopted on the 28th of July, 1860. The former of these laws passed the legislative body by a vote of 246 against 4, the latter with but a single negative voice. The influence of the Government, in a country where the throne is so potent as in France, would account for a large majority, but when it is considered that both laws, the former especially, interfere very materially with the rights of private domain, the almost entire unanimity with which they were adopted is proof of a very general popular conviction, that the protection and extension of the forests is a measure more likely than any other to arrest the devastations of the torrents and check the violence, if not to prevent the recurrence, of destructive river inundations. The law of July 28th, 1860, appropriated 10,000,000 francs, to be expended, at the rate of 1,000,000 francs per year, in executing or aiding the replanting of woods. It is computed that this appropriation—which, considering the vast importance of the subject, does not seem extravagant for a nation rich enough to be able to expend annually six hundred times that sum in the maintenance of its military establishments in times of peace—will secure the creation of new forest to the extent of about 200,000 acres, or one fourteenth part of the soil, where the restoration of the woods is thought feasible, and, at the same time, specially important as a security against the evils ascribed, in a great measure, to its destruction.[*]

In 1865 the Legislative Assembly passed a bill amendatory of the law of 1860, providing, among other things, for securing the soil in exposed localities by grading, and by promoting the growth of grass and the formation of greensward over the surface. This has proved a most beneficial measure, and its adoption under corresponding conditions in the United States is most highly to be recommended. The leading features of the system are:

1. Marking out and securing from pasturage and all other encroachments a zone along the banks and around the head of ravines.

2. Turfing this zone, which in France accomplishes itself, if not spontaneously, at least with little aid from art.

3. Consolidation of the scarps of the ravines by grading and wattling and establishing barriers, sometimes of solid masonry, but generally of fascines or any other simple materials at hand, across the bed of the stream.

---

[*] In 1848 the Government of the so-called French Republic sold to the Bank of France 187,000 acres of public forests, and notwithstanding the zeal with which the Imperial Government had pressed the protective legislation of 1860, it introduced into the Legislative Assembly in 1865 a bill for the sale, and consequently destruction, of the forests of the state to the amount of one hundred million francs. The question was much debated in the Assembly, and public opinion manifested itself so energetically against the measure that the ministry felt itself compelled to withdraw it. See the discussions in *L'Aliénation des Forêts de l'État.* Paris, 1865.

The late Imperial Government sold about 170,000 acres of woodland between 1852 and 1866, both inclusive. The other Governments, since the restoration of the Bourbons in 1814, alienated more than 700,000 acres of the public forests, exclusive of sales between 1836 and 1857, which are not reported.—*Annuaire des Eaux et Forêts*, 1872, p. 9.

4. Cutting *banquettes* or narrow terraces along the scarps, and planting rows of small deciduous trees and arborescent shrubs upon them, alternating with belts of grass obtained by turfing with sods or sowing grass-seeds. Planting the banquettes and slopes with bushes, and sowing any other vegetables with tenacious roots, is also earnestly recommended.*

Remedies against Torrents.

The rural population, which in France is generally hostile to all forest laws, soon acquiesced in the adoption of this system, and its success has far surpassed all expectation. At the end of the year 1868 about 190,000 acres had been planted with trees,† and nearly 7,000 acres well turfed over in the Department of the Hautes Alpes. Many hundred ravines, several of which had been the channels of formidable torrents, had been secured by barriers, grading and planting, and according to official reports the aspect of the mountains in the Department, wherever these methods were employed, had rapidly changed. The soil had acquired such stability that the violent rains of 1868, so destructive elsewhere, produced no damage in the districts which had been subjected to these operations, and numerous growing torrents which threatened irreparable mischief had been completely extinguished, or at least rendered altogether harmless.‡

Besides the processes directed by the Government of France, various subsidiary measures of an easily and economically practicable character have been suggested. Among them is one which has long been favorably known in our Southern States under the name of *circling*, and the adoption of which in hilly regions in other States is to be strongly recommended.

---

* See a description of similar processes recommended and adopted by Mengotti, in his *Idraulica*, vol. ii., chap. xvii.

† Travellers spending the winter at Nice may have a good opportunity of studying the methods of forming and conducting the rewooding of mountain slopes, under the most unfavorable conditions, by visiting Mont Boron, in the immediate vicinity of that city, and other coast plantations in that province, where great difficulties have been completely overcome by the skill and perseverance of French foresters. See *Les Forêts des Maures*, *Revue des Eaux et Forêts*, January, 1869.

‡ For ample details of processes and results, see the second volume of SURELL, *Étude sur les Torrents*, Paris, 1872, and a Report by DE LA GRYE, in the *Revue des Eaux et Forêts* for January, 1869.

It is simply a method of preventing the wash of surface by rains, and at the same time of providing a substitute for irrigation of steep pasture-grounds, consisting in little more than in running horizontal furrows along the hillsides, thus converting the scarp of the hills into a succession of small terraces which, when once turfed over, are very permanent. Experience is said to have demonstrated that this simple process at least partially checks the too rapid flow of surface-water into the valleys, and, consequently, in a great measure obviates one of the most prominent causes of inundations, and that it suffices to retain the water of rains, of snows, and of small springs, long enough for the irrigation of the soil, thus increasing its product of herbage in a fivefold proportion.*

As a further recommendation, it may be observed that this process is an admirable preparation of the ground for forest plantations, as young trees planted on the terraces would derive a useful protection from the form of the surface and the coating of turf, and would also find a soil moist enough to secure their growth.

Forests of Italy.

According to the most recent statistics, Italy has 17.64 per cent. of woodland,† a proportion which, considering the character of climate and surface, the great amount of soil which is fit for no other purpose than the growth of trees, and the fact that much of the land classed as forest is either very imperfectly wooded, or covered with groves badly administered, and not in a state of progressive improvement, might advantageously be doubled. Taking Italy as a whole, we may say that she is eminently fitted by climate, soil, and superficial formation, to the growth of a varied and luxuriant arboreal vegetation, and that in the interests of self-protection, the promotion of forestal industry is among the first duties of her people. There are in Western Piedmont valleys where the felling of the woods has produced consequences geographically and economically as disastrous as in South-eastern France, and there are many other districts in the Alps and the Apennines where human improvidence has been almost equally destructive. Some of these regions must be abandoned to absolute desolation, and for others the opportunity of physical restoration is rapidly passing away. But there are still millions of square miles which might profitably be planted with forest-trees, and thousands of acres of parched and barren hillside, within sight of almost every Italian provincial capital, which might easily and shortly be reclothed with verdant woods.*

---

* TROY, *Étude sur le Reboisement des Montagnes*, §§ 6, 7, 21.

† SIEMONI, *Manuale d'Arte Forestale*, 2 ediz., Firenze, 1872, p. 542.

The denudation of the Central and Southern Apennines and of the Italian declivity of the Western Alps began at a period of unknown antiquity, but it does not seem to have been carried to a very dangerous length until the foreign conquests and extended commerce of Rome created a greatly increased demand for wood for the construction of ships and for military material.[*] The Eastern Alps, the Western Apennines, and the Maritime Alps retained their forests much later; but even here the want of wood, and the injury to the plains and the navigation of the rivers by sediment brought down by the torrents, led to legislation for the protection of the forests, by the Republic of Venice, at various periods between the fifteenth and the nineteenth centuries,[†] by that of Genoa as early at least as the seventeenth; and both these Governments, as well as several others, passed laws requiring the proprietors of mountain-lands to replant the woods. These, however, seem to have been little observed, and it is generally true that the present condition of the forest in Italy is much less due to the want of wise legislation for its protection than to the laxity of the Governments in enforcing their laws.

---

* To one accustomed to the slow vegetation of less favored climes, the rapidity of growth in young plantations in Italy seems almost magical. The trees planted along the new drives and avenues in Florence have attained in three or four years a development which would require at least ten in our Northern States. This, it is true, is a special case, for the trees have been planted and tended with a skill and care which cannot be bestowed upon a forest; but the growth of trees little cared for is still very rapid in Italy. According to Toscanelli, *Economia rurale nella Provincia di Pisa*, p. 8, *note*—one of the most complete, curious, and instructive pictures of rural life which exists in any literature—the white poplar, *Populus alba*, attains in the valley of the Serchio a great height, with a mean diameter of two feet, in twenty years. Selmi states in his *Miasma Palustre*, p. 115, that the linden reaches a diameter of sixteen inches in the same period. The growth of foreign trees is sometimes extremely luxuriant in Italy. Two Atlas cedars, at the well-known villa of Careggi, near Florence, grown from seed sown in 1850, measure twenty inches in diameter, above the swell of the roots, with an estimated height of sixty feet.

---

[*] An interesting example of the collateral effects of the destruction of the forests in ancient Italy may be found in old Roman architecture. In the oldest brick constructions of Rome the bricks are very thin, very thoroughly burnt, and laid with a thick stratum of mortar between the courses. A few centuries later the bricks were thicker and less well burnt, and the layers of mortar were thinner. In the Imperial period the bricks were still thicker, generally soft-burnt, and with little mortar between the courses. This fact, I think, is due to the abundance and cheapness of fuel in earlier, and its growing scarceness and dearness in later, ages. When wood cost little, constructors could afford to burn their brick thoroughly, and to burn and use a great quantity of lime. As the price of fire-wood advanced, they were able to consume less fuel in brick- and lime-kilns, and the quality and quantity of brick and lime used in building were gradually reversed in proportion.

The multitude of geographical designations in Italy which indicate the former existence of forests show that even in the Middle Ages there were woods where no forest-trees are now to be found. There are hundreds of names of mediæval towns derived from *abete*, *acero*, *carpino*, *castagno*, *faggio*, *frassino*, *pino*, *quercia*, and other names of trees.

[†] See A. de Berenger's valuable *Saggio Storico della Legislazione Veneta Forestale*. Venezia, 1863.

We do not find in the Venetian forestal legislation much evidence that geographical arguments were taken into account by the lawgivers, who seem to have had an eye only to economical considerations.

According to Hummel, the desolation of the Karst, the high plateau lying north of Trieste, now one of the most parched and barren districts in Europe, is owing to the felling of its woods, centuries ago, to build the navies of Venice. "Where the miserable peasant of the Karst now sees nothing but bare rock swept and scoured by the raging Bora, the fury of this wind was once subdued by mighty firs, which Venice recklessly cut down to build her fleets."—*Physische Geographie*, p. 32.

It is very common in Italy to ascribe to the French occupation under the first Empire all the improvements and all the abuses of recent times, according to the political sympathies of the individual; and the French are often said to have prostrated every forest which has disappeared within this century. But, however this may be, no energetic system of repression or restoration was adopted by any of the Italian States after the downfall of the Empire, and the taxes on forest property in some of them were so burdensome that rural municipalities sometimes proposed to cede their common woods to the Government, without any other compensation than the remission of the taxes imposed on forest-lands.* Under such circumstances, woodlands would soon become disafforested, and where facilities of transportation and a good demand for timber have increased the inducements to fell it, as upon the borders of the Mediterranean, the destruction of the forest and all the evils which attend it have gone on at a seriously alarming rate.

Gallenga gives a striking account of the wanton destruction of the forests in Northern Italy within his personal recollection,† and there are few Italians past middle life whose own memory will not supply similar reminiscences. The clearing of the mountain valleys of the provinces of Bergamo and of Brescia is recent, and Lombardini informs us the felling of the woods in the Valtelline commenced little more than forty years ago.

Although no country has produced more able writers on the value of the forest and the general consequences of its destruction than Italy, yet the specific geographical importance of the woods, except as a protection against inundations, has not been so clearly recognized in that country as in the States bordering it on the north and west. It is true that the face of nature has been as completely revolutionized by man, and that the action of torrents has created almost as wide and as hopeless devastation in Italy as in France; but in the French Empire the recent desolation produced by clearing the forests is more extensive, has been more suddenly effected, has occurred in less remote and obscure localities, and, therefore, excites a livelier and more general interest than in Italy, where public opinion does not so readily connect the effect with its true cause. Italy, too, from ancient habit, employs little wood in architectural construction; for generations she has maintained no military or commercial marine large enough to require exhaustive quantities of timber,* and the mildness of her climate makes small demands on the woods for fuel. Besides these circumstances, it must be remembered that the sciences of observation did not become knowledges of practical application till after the mischief was already mainly done and even forgotten in Alpine Italy, while its evils were just beginning to be sensibly felt in France when the claims of natural philosophy as a liberal study were first acknowledged in modern Europe. The former political condition of the Italian Peninsula would have effectually prevented the adoption of a general system of forest economy, however clearly the importance of a wise administration of this great public interest might have been understood. The woods which controlled and regulated the flow of the river-sources were very often in one jurisdiction, the plains to be irrigated, or to be inundated by floods and desolated by torrents, in another. Concert of action, on such a subject, between a multitude of jealous petty sovereignties, was obviously impossible, and nothing but the permanent union of all the Italian States under a single government can render practicable the establishment of such arrangements for the conservation and restoration of the forests, and the regulation of the flow of the waters, as are necessary for the full development of the yet unexhausted resources of that fairest of lands, and even for the maintenance of the present condition of its physical geography.

---

* See the *Politecnico* for the month of May, 1862, p. 234.

† "Far away in the darkest recesses of the mountains a kind of universal conspiracy seems to have been got up among these Alpine people,—a destructive mania to hew and sweep down everything that stands on roots."—*Country Life in Piedmont*, p. 134.

"There are huge pyramids of mountains now bare and bleak from base to summit, which men still living and still young remember seeing richly mantled with all but primeval forests."—*Ibid.*, p. 135.

---

* The great naval and commercial marines of Venice and of Genoa must have occasioned an immense consumption of lumber in the Middle Ages, and the centuries immediately succeeding those commonly embraced in that designation. The marine construction of that period employed larger timbers than the modern naval architecture of most commercial countries, but apparently without a proportional increase of strength. The old modes of ship-building have been, to a considerable extent, handed down to very recent times in the Mediterranean, and though better models and modes of construction are now employed in Italian shipyards, an American or an Englishman looks with astonishment at the huge beams and thick planks so often employed in the construction of very small vessels navigating that sea, and not yet old enough to be broken up as unseaworthy.

The Forests of Germany.

Germany, including a considerable part of the Austrian Empire, from character of surface and climate, and from the attention which has long been paid in all the German States to sylviculture, is in a far better condition in this respect than its more southern neighbors; and though in the Alpine provinces of Bavaria and Austria the same improvidence which marks the rural economy of the corresponding districts of Switzerland, Italy, and France, has produced effects hardly less disastrous,*

---

* As an instance of the scarcity of fuel in some parts of the territory of Bavaria, where, not long since, wood abounded, I may mention the fact that the water of salt-springs is, in some instances, conveyed to the distance of sixty miles, in iron pipes, to reach a supply of fuel for boiling it down.

In France, the juice of the sugar-beet is sometimes carried three or four miles in pipes for the same reason.

Many of my readers may remember that it was not long ago proposed to manufacture the gas for the supply of London at the mouths of the coal-mines, and convey it to the city in pipes, thus saving the transportation of the coal; but as the coke and mineral tar would still have remained to be disposed of, the operation would probably not have proved advantageous.

Great economy in the production of petroleum has resulted from the application of cast-iron tubes to the wells. instead of barrels; the oil is thus carried yet, as a whole, the German States, as Siemoni well observes, must be considered as in this respect the model countries of Europe. Not only is the forest area in general maintained without diminution, but new woods are planted where they are specially needed,* and, though the slow growth of forest-trees in those climates reduces the direct pecuniary returns of woodlands to a minimum, the governments wisely persevere in encouraging this industry. The exportation of sawn lumber from Trieste is large, and in fact the Turkish and Egyptian markets are in great part supplied from this source.†

Forests of Russia.

Russia, which we habitually consider as substantially a forest country—which has in fact a large proportion of woodland—is beginning to suffer seriously for want of wood. Jourdier observes: "Instead of a vast territory with immense forests, which we expect to meet, one sees only scattered groves thinned by the wind or by the axe of the *moujik*, grounds cut over and more or less recently cleared for cultivation. There is probably not a single district in Russia which has not to deplore the ravages of man or of fire, those two great enemies of Muscovite sylviculture. This is so true, that clear-sighted men already foresee a crisis which will become terrible, unless the discovery

---

over the various inequalities of surface for three or four miles to the tanks on the railroads, and forced into them by steam-engines. The price of transport is thus reduced one-fifth.

* The Austrian Government is making energetic efforts for the propagation of forests on the desolate waste of the Karst. The difficulties from drought and from the violence of the winds, which might prove fatal to young and even to somewhat advanced plantations, are very serious, but in 1866 upwards of 400,000 trees had been planted and great quantities of seeds sown. Thus far, the results of this important experiment are said to be encouraging. See the *Chronique Forestière* in the *Revue des Eaux et Forêts*, Feb. 1870.

† For information respecting the forests of Germany, as well as other European countries, see, besides the works already cited, the very valuable *Manuale d'Arte Forestale* of Siemoni, 2de edizione, Firenze, 1872.

of great deposits of some new combustible, as pit-coal or anthracite, shall diminish its evils." *

---

* CLAVÉ, *Études sur l'Économie Forestière*, p. 261. Clavé adds (p. 262): "The Russian forests are very unequally distributed through the territory of this vast empire. In the north they form immense masses, and cover whole provinces, while in the south they are so completely wanting that the inhabitants have no other fuel than straw, dung, rushes, and heath." . . . "At Moscow, firewood costs thirty per cent. more than at Paris, while, at the distance of a few leagues, it sells for a tenth of that price."

This state of things is partly due to the want of facilities of transportation, and some parts of the United States are in a similar condition. During a severe winter, ten or twelve years ago, the sudden freezing of the canals and rivers, before a large American town had received its usual supply of fuel, occasioned an enormous rise in the price of wood and coal, and the poor suffered severely for want of it. Within a few hours of the city were large forests and an abundant stock of firewood felled and prepared for burning. This might easily have been carried to town by the railroads which passed through the woods; but the managers of the roads refused to receive it as freight, because a rival market for wood might raise the price of the fuel they employed for their locomotives. Truly, our railways "want a master."

Hohenstein, who was long professionally employed as a forester in Russia, describes the consequences of the general war upon the woods in that country as already most disastrous, and as threatening still more ruinous evils. The river Volga, the life artery of Russian internal commerce, is drying up from this cause, and the great Muscovite plains are fast advancing to a desolation like that of Persia.—*Der Wald*, p. 223.

The level of the Caspian Sea is eighty-three feet lower than that of the Sea of Azoff, and the surface of Lake Aral is fast sinking. Von Baer maintains that the depression of the Caspian was produced by a sudden subsidence, from geological causes, and not gradually by excess of evaporation over supply. See *Kaspische Studien*, p. 25. But this subsidence diminished the area and consequently the evaporation of that sea, and the rivers which once maintained its ancient equilibrium ought to have raised it to its former level, if their own flow had not been diminished. It is, indeed, not proved that the laying bare of a wooded country diminishes the total annual precipitation upon it; but it is certain that the summer delivery of water from the surface of a champaign region, like that through which the Volga, its tributaries, and the feeders of Lake Aral, flow, is lessened by the removal of its woods. Hence, though as much rain may still fall in the valleys of those rivers as when their whole surface was covered with forests, more moisture may be carried off by evaporation, and a less quantity of water be discharged by the rivers since their basins were cleared, and therefore the present condition of the inland waters in question may be due to the removal of the forests in their valleys and the adjacent plains.

Forests of United States.

I greatly doubt whether any one of the American States, except, perhaps, Oregon, has, at this moment, more woodland than it ought permanently to preserve, though, no doubt, a different distribution of the forests in all of them might be highly advantageous. It is, perhaps, a misfortune to the American Union that the State Governments have so generally disposed of their original domain to private citizens. It is true that public property is not sufficiently respected in the United States; and within the memory of almost every man of mature age, timber was of so little value in the northernmost States that the owners of private woodlands submitted, almost without complaint, to what would be regarded elsewhere as very aggravated trespasses upon them.* Persons in want of timber helped themselves to it wherever they could find it, and a claim for damages, for so insignificant a wrong as cutting down and carrying off a few pine or oak trees, was regarded as a mean-spirited act in a proprietor. The habits formed at this period are not altogether obsolete, and even now the notion of a common right of property in the woods still lingers, if not as an opinion at least as a sentiment. Under such circumstances it has been difficult to protect the forest, whether it belong to the State or to individuals. Property of this kind is subject to plunder, as well as to frequent damage by fire. The destruction from these causes would, indeed, considerably lessen, but would by no means wholly annihilate the climatic and geographical influences of the forest, or ruinously diminish its value as a regular source of supply of fuel and timber.

---

* According to the maxims of English jurisprudence, the common law consists of general customs so long established that "the memory of man runneth not to the contrary." In other words, long custom makes law. In new countries, the change of circumstances creates new customs, and, in time, new law, without the aid of legislation. Had the American colonists observed a more sparing economy in the treatment of their woods, a new code of customary forest-law would have sprung up and acquired the force of a statute. Popular habit was fast elaborating the fundamental principles of such a code, when the rapid increase in the value of timber, in consequence of the reckless devastation of the woodlands, made it the interest of the proprietors to interfere with this incipient system of forest jurisprudence, and appeal to the rules of English law for the protection of their woods. The courts have sustained these appeals, and forest property is now legally as inviolable as any other, though common opinion still combats the course of judicial decision on such questions.

It is evidently a matter of the utmost importance that the public, and especially land-owners, be roused to a sense of the dangers to which the indiscriminate clearing of the woods may expose not only future generations, but the very soil itself. Some of the American States, as well as the Governments of many European colonies, still retain the ownership of great tracts of primitive woodland. The State of New York, for example, has, in its north-eastern counties, a vast extent of territory in which the lumberman has only here and there established his camp, and where the forest, though interspersed with permanent settlements, robbed of some of its finest pine groves, and often ravaged by devastating fires, still covers far the largest proportion of the surface. Through this territory the soil is generally poor, and even the new clearings have little of the luxuriance of harvest which distinguishes them elsewhere. The value of the land for agricultural uses is therefore very small, and few purchases are made for any other purpose than to strip the soil of its timber. It has been often proposed that the State should declare the remaining forest the inalienable property of the commonwealth, but I believe the motive of the suggestion has originated rather in poetical than in economical views of the subject. Both these classes of considerations have a real worth. It is desirable that some large and easily accessible region of American soil should remain, as far as possible, in its primitive condition, at once a museum for the instruction of the student, a garden for the recreation of the lover of nature, and an asylum where indigenous tree, and humble plant that loves the shade, and fish and fowl and four-footed beast, may dwell and perpetuate their kind, in the enjoyment of such imperfect protection as the laws of a people jealous of restraint can afford them. The immediate loss to the public treasury from the adoption of this policy would be inconsiderable, for these lands are sold at low rates. The forest alone, economically managed, would, without injury, and even with benefit to its permanence and growth, soon yield a regular income larger than the present value of the fee.

The collateral advantages of the preservation of these forests would be far greater. Nature threw up those mountains and clothed them with lofty woods, that they might serve as a reservoir to supply with perennial waters the thousand rivers and rills that are fed by the rains and snows of the Adirondacks, and as a screen for the fertile plains of the central counties against the chilling blasts of the north wind, which meet no other barrier in their sweep from the Arctic pole. The climate of Northern New York even now presents greater extremes of temperature than that of Southern France. The long-continued cold of winter is more intense, the short heats of summer even fiercer than in Provence, and hence the preservation of every influence that tends to maintain an equilibrium of temperature and humidity is of cardinal importance. The felling of the Adirondack woods would ultimately involve for Northern and Central New York consequences similar to those which have resulted from the laying bare of the southern and western declivities of the French Alps and the spurs, ridges, and detached peaks in front of them.

It is true that the evils to be apprehended from the clearing of the mountains of New York may be less in degree than those which a similar cause has produced in Southern France, where the intensity of its action has been increased by the inclination of the mountain declivities, and by the peculiar geological constitution of the earth. The degradation of the soil is, perhaps, not equally promoted by a combination of the same circumstances, in any of the American Atlantic States, but still they have rapid slopes and loose and friable soils enough to render widespread desolation certain, if the further destruction of the woods is not soon arrested. The effects of clearing are already perceptible in the comparatively unviolated region of which I am speaking. The rivers which rise in it flow with diminished currents in dry seasons, and with augmented volumes of water after heavy rains. They bring down larger quantities of sediment, and the increasing obstructions to the navigation of the Hudson, which are extending themselves down the channel in proportion as the fields are encroaching upon the forest, give good grounds for the fear of irreparable injury to the commerce of the important towns on the upper waters of that river, unless measures are taken to prevent the expansion of "improvements" which have already been carried beyond the demands of a wise economy.

In the Eastern United States the general character of the climate, soil, and surface is such, that for the formation of very destructive torrents a much longer time is required than would be necessary in the mountainous provinces of Italy or of France. But the work of desolation has begun even there, and wherever a rapid mountain-slope has been stripped of wood, incipient ravines already plough the surface, and collect the precipitation in channels which threaten serious mischief in the future. There is a peculiar action of this sort on the sandy surface of pine-forests and in other soils that unite readily with water, which has excited the attention of geographers and geologists. Soils of the first kind are found in all the Eastern States; those of the second are more frequent in the exhausted counties of Maryland, where tobacco is cultivated, and in the more southern territories of Georgia and Alabama. In these localities the ravines which appear after the cutting of the forest, through some accidental disturbance of the surface, or, in some formations, through the cracking of the soil in consequence of great drought or heat, enlarge and extend themselves with fearful rapidity.

In Georgia and in Alabama, Lyell saw "the beginning of the formation of hundreds of valleys in places where the primitive forest had been recently cut down." One of these, in Georgia, in a soil composed of clay and sand produced by the decomposition *in situ* of hornblendic gneiss with layers and veins of quartz, "and which did not exist before the felling of the forest twenty years previous," he describes as more than 55 feet in depth, 300 yards in length, and from 20 to 180 feet in breadth. Our author refers to other cases in the same States, "where the cutting down of the trees, which had prevented the rain from collecting into torrents and running off in sudden land-floods, has given rise to ravines from 70 to 80 feet deep." [*]

Similar results often follow in the North-eastern States from cutting the timber on the "pine plains," where the soil is usually of a sandy composition and loose texture.

American Forest-Trees.

The remaining forests of the Northern States and of Canada no longer boast the mighty pines which almost rivalled the gigantic sequoia and redwood of California; and the growth of the larger forest-trees is so slow, after they have attained to a certain size, that if every pine and oak were spared for two centuries, the largest now standing would not reach the stature of hundreds recorded to have been cut within two or three generations.[†] Dr. Williams, who wrote about sixty years ago,

---

[*] LYELL, *Principles of Geology*, 10th ed., vol. i., 345–6.

[†] The growth of the white pine, on a good soil and in open ground. is rather rapid until it reaches the diameter of a couple of feet, after which it is much slower. The favorite habitat of this tree is light, sandy earth. On this soil, and in a dense wood, it requires a century to attain the diameter of a yard. Emerson (*Trees of Massachusetts*, p. 65), says that a pine of this species, near Paris, "thirty years planted, is eighty feet high, with a diameter of three feet." He also states that ten white pines planted at Cambridge, Massachusetts, in 1809 or 1810, exhibited, in the winter of 1841 and 1842, an average of twenty inches diameter at the ground, the two largest measuring, at the height of three feet, four feet eight inches in circumference; and he mentions another pine growing in a rocky swamp, which, at the age of thirty-two years, "gave seven feet in circumference at the but, with a height of sixty-two feet six inches." This latter I suppose to be a seedling, the others *transplanted* trees, which might have been some years old when placed where they finally grew.

The following case came under my own observation: In 1824 a pine-tree, states the following as the dimensions of "such trees as are esteemed large ones of their kind in that part of America" [Vermont], qualifying his account with the remark that his measurements "do not denote the greatest which nature has produced of their particular species, but the greatest which are to be found in most of our towns."

	Diameter.	Height.
Pine..................	6 feet,	247 feet.
Maple.................	5 " 9 inches,	From 100 to 200 feet.
Buttonwood...........	5 " 6 "	
Elm....................	5 "	
Hemlock...............	4 " 9 "	
Oak....................	4 "	
Basswood.............	4 "	
Ash....................	4 "	
Birch..................	4 "	

He adds a note saying that a white pine was cut in Dunstable, New Hampshire, in the year 1736, the diameter of which was seven feet and eight inches. Dr. Dwight says that a fallen pine in Connecticut was found to measure two hun-

---

so small that a young lady, with the help of a lad, took it up from the ground and carried it a quarter of a mile, was planted near a house in a town in Vermont. It was occasionally watered, but received no other special treatment. I measured this tree in 1860, and found it, at four feet from the ground, and entirely above the spread of the roots, two feet and four inches in diameter. A new measurement in 1871 gave a diameter of two feet eight inches, being an increase of four inches in eleven years, a slower rate than that of preceding years. It could not have been more than three inches through when transplanted, and up to 1860 must have increased its diameter at the rate of about seven-tenths of an inch per year, almost double its later growth. In 1871 the crown had a diameter of 62 feet.

In the same neighborhood, elms transplanted in 1803, when they were not above three or four inches through, had attained, in 1871, a diameter of from four feet to four feet two inches, with a spread of crown of from 90 to 112 feet. Sugar-maples, transplanted in 1822, at about the same size, measured two feet three inches through. This growth undoubtedly considerably exceeds that of trees of the same species in the natural forest, though the transplanted trees had received no other fertilizing application than an unlimited supply of light and air.

dred and forty-seven feet in height, and adds: "A few years since, such trees were in great numbers along the northern parts of Connecticut River." In another letter, he speaks of the white pine as "frequently six feet in diameter, and two hundred and fifty feet in height," and states that a pine had been cut in Lancaster, New Hampshire, which measured two hundred and sixty-four feet. Emerson wrote in 1846: "Fifty years ago, several trees growing on rather dry land in Blandford, Massachusetts, measured, after they were felled, two hundred and twenty-three feet." All these trees are surpassed by a pine felled at Hanover, New Hampshire, about a hundred years ago, and described as measuring two hundred and seventy-four feet.* These descriptions, it will be noticed, apply to trees cut from seventy to one hundred and forty years since.

Persons, whom observation has rendered familiar with the present character of the American forest, will be struck with the smallness of the diameter which Dr. Williams and Dr. Dwight ascribe to trees of such extraordinary height. Individuals of the several species mentioned in Dr. Williams's table are now hardly to be found in the same climate, exceeding one-half or at most two-thirds of the height which he assigns to them; but, except in the case of the oak and the pine, the diameter stated by him would not be thought very extraordinary in trees of far less height, now standing. Even in the species I have excepted, those diameters, with half the heights of Dr. Williams, might perhaps be paralleled at the present time; and many elms, transplanted, at a diameter of six inches, within the memory of persons still living, measure four and sometimes even five feet through. For this change in the growth of forest-trees there are two reasons: the one is, that the great commercial value of the pine and the oak have caused the destruction of all the best—that is, the tallest and straightest—specimens of both; the other, that the thinning of the woods by the axe of the lumberman has allowed the access of light and heat and air to trees of humbler worth and lower stature, which have survived their more towering brethren. These, consequently, have been able to expand their crowns and swell their stems to a degree not possible so long as they were overshadowed and stifled by the lordly oak and pine. While, therefore, the New England forester must search long before he finds a pine

---

* WILLIAMS, *History of Vermont*, ii., p. 53. DWIGHT'S *Travels*, iv., p. 21, and iii., p. 36. EMERSON, *Trees of Massachusetts*, p. 61. PARISH, *Life of President Wheelock*, p. 56.

> fit to be the mast
> Of some great ammiral,

beeches and elms and birches, as sturdy as the mightiest of their progenitors, are still no rarity.*

California fortunately still preserves her magnificent sequoias, which rise to the height of three hundred feet, and sometimes, as we are assured, even to three hundred and sixty and four hundred feet, and she has also pines and cedars of scarcely inferior dimensions. The public being now convinced of the importance of preserving these colossal trees, it is very probable that the fear of their total destruction may prove groundless, and we may still hope that some of them may survive even till that distant future when the skill of the forester shall have raised from their seeds a progeny as lofty and as majestic as those which now exist.*

---

* The forest-trees of the Northern States do not attain to extreme longevity in the dense woods. Dr. Williams found that none of the huge pines, the age of which he ascertained, exceeded three hundred and fifty or four hundred years, though he quotes a friend who thought he had noticed trees considerably older. The oak lives longer than the pine, and the hemlock-spruce is perhaps equally long lived. A tree of this latter species, cut within my knowledge in a thick wood, counted four hundred and eighty-six, or, according to another observer, five hundred annual circles.

Great luxuriance of animal and vegetable production is not commonly accompanied by long duration of the individual. The oldest men are not found in the crowded city; and in the tropics, where life is prolific and precocious, it is also short. The most ancient forest-trees of which we have accounts have not been those growing in thick woods, but isolated specimens, with no taller neighbor to intercept the light and heat and air, and no rival to share the nutriment afforded by the soil.

The more rapid growth and greater dimensions of trees standing near the boundary of the forest, are matters of familiar observation. "Long experience has shown that trees growing on the confines of the wood may be cut at sixty years of age as advantageously as others of the same species, reared in the depth of the forest, at a hundred and twenty. We have often remarked, in our Alps, that the trunk of trees upon the border of a grove is most developed or enlarged upon the outer or open side, where the branches extend themselves farthest, while the concentric circles of growth are most uniform in those entirely surrounded by other trees, or standing entirely alone."—A. and G. VILLA, *Necessità dei Boschi*, pp. 17, 18.

European and American Trees compared.

The woods of North America are strikingly distinguished from those of Europe by the vastly greater variety of species they contain. According to Clavé, there are in "France and in most parts of Europe only about twenty forest-trees, five or six of which are spike-leaved and resinous, the remainder broad-leaved." † Our author, however, doubtless means genera, though he uses the word *espèces*. Rossmässler enumerates fifty-seven species of forest-trees as found in Germany, but some of these are mere shrubs, some are fruit and properly garden trees, and some others are only varieties of familiar species. The valuable manual of Parade describes about the same number, including, however, two of American origin—the locust, *Robinia pseudacacia*, and the Weymouth or white pine, *Pinus strobus*—and the cedar of Lebanon from Asia, which, or at least a very closely allied species, is indigenous in Algeria also. We may then safely say that Europe does not possess above forty or fifty native trees of such economical value as to be worth the special care of the forester, while the oak alone numbers more than thirty species in the United States,* and some other North American genera are almost equally diversified.†

---

* California must surrender to Australia the glory of possessing the tallest trees. According to Dr. Mueller, Director of the Government Botanic Garden at Melbourne, a *Eucalyptus*, near Healesville, measured 480 feet in height. Later accounts speak of trees of the same species fully 500 feet in height. See SCHLEIDEN, *Für Baum und Wald*, p. 21.

If we may credit late reports, the growth of the eucalyptus is so rapid in California, that the child is perhaps now born who will see the tallest sequoia overtopped by this new vegetable emigrant from Australia.

† *Études Forestières*, p. 7.

---

* For full catalogues of American forest-trees, and remarks on their geographical distribution, consult papers on the subject by Dr. J. G. Cooper, in the Report of the Smithsonian Institution for 1858, and the Report of the United States Patent Office, Agricultural Division, for 1860.

† Although Spenser's catalogue of trees occurs in the first canto of the first book of the "Faëry Queene"—the only canto of that exquisite poem actually read by most students of English literature—it is not so generally familiar as to make the quotation of it altogether superfluous:

VII.

Enforst to seeke some covert nigh at hand,
A shadie grove not farr away they spide,
That promist ayde the tempest to withstand;
Whose loftie trees, yclad with sommers pride,
Did spred so broad, that heavens light did hide,
Not perceable with power of any starr:
And all within were pathes and alleies wide,
With footing worne, and leading inward farr;
Faire harbour that them seems; so in they entered ar.

VIII.

And foorth they passe, with pleasure forward led,
Joying to heare the birdes sweete harmony,
Which therein shrouded from the tempest dred,
Seemd in their song to scorne the cruell sky.
Much can they praise the trees so straight and hy,
The sayling pine: the cedar stout and tall;
The vine-propp elm; the poplar never dry;
The builder oake, sole king of forrests all;
The aspine good for staves; the cypresse funerall;

IX.

The laurell, meed of mightie conquerours
And poets sage; the firre that weepeth still;
The willow, worne of forlorn paramours;
The eugh, obedient to the benders will;
The birch for shaftes; the sallow for the mill;
The mirrhe sweete-bleeding in the bitter wound;
The warlike beech; the ash for nothing ill;
The fruitfull olive; and the platane round;
The carver holme; the maple seeldom inward sound.

Although the number of *species* of American forest-trees is much larger than of European, yet the distinguishable *varieties* are relatively more numermay perhaps be better adapted to this purpose than any of the pines of the New World, and it is of great importance for its turpentine, resin, and tar. The épicéa, or common fir, *Abies picea*, *Abies excelsa*, *Picea excelsa*, abundant in the mountains of France and the contiguous country, is known for its product, Burgundy pitch, and, as it flourishes in a greater variety of soil and climate than almost any other spike-leaved tree, it might be well worth transplantation.* The cork oak has been introduced into California and some other parts of the United States, I believe, and would undoubtedly thrive in the Southern section of the Union.†

---

* This fir is remarkable for its tendency to cicatrize or heal over its stumps, a property which it possesses in common with some other firs, the maritime pine, and the European larch. When these trees grow in thick clumps, their roots are apt to unite by a species of natural grafting, and if one of them be felled, although its own proper rootlets die, the stump may continue, sometimes for a century, to receive nourishment from the radicles of the surrounding trees, and a dome of wood and bark of considerable thickness be formed over it. The healing is, however, only apparent, for the entire stump, except the outside ring of annual growth, soon dies, and even decays within its covering, without sending out new shoots. See *Monthly Report, Department of Agriculture*, for October, 1872.

† At the age of twelve or fifteen years, the cork-tree is stripped of its outer bark for the first time. This first yield is of inferior quality, and is employed for floats for nets and buoys, or burnt for lampblack. After this, a new layer of cork, an inch or an inch and a quarter in thickness, is formed about once in ten years, and is removed in large sheets without injury to the tree, which lives a hundred and fifty years or more. According to Clavé (p. 252), the annual product of a forest of cork oaks is calculated at about 660 kilogrammes, worth 150 francs, to the hectare, which, deducting expenses, leaves a profit of 100 francs. This is about equal to 250 pound weight, and eight dollars profit to the acre. The cork oaks of the national domain in Algeria cover about 500,000 acres, and are let to individuals at rates which are expected, when the whole is rented, to yield to the state a revenue of about $2,000,000.

George Sand, in the *Histoire de ma Vie*, speaks of the cork-forests in Southern France as among the most profitable of rural possessions, and states, what I do not remember to have seen noticed elsewhere, that Russia is the best customer for cork. The large sheets taken from the trees are slit into thin plates, and used to line the walls of apartments in that cold climate. On the cultivation and management of the cork oak, see *Des Incendies et de la culture du Chêne-liège*, in *Revue des Eaux et Forêts* for February, 1869.

In the walnut, the chestnut, the cork oak, the mulberry, the olive, the orange, the lemon, the fig, and the multitude of other trees which, by their fruit, or by other products, yield an annual revenue, nature has provided Southern Europe with a partial compensation for the loss of the native forest. It is true that these trees, planted as most of them are at such distances as to admit of cultivation, or of the growth of grass among them, are but an inadequate substitute for the thick and shady wood; but they perform to a certain extent the same offices of absorption and transpiration, they shade the surface of the ground, they serve to break the force of the wind, and on many a steep declivity, many a bleak and barren hillside, the chestnut binds the soil together with its roots, and prevents tons of earth and gravel from washing down upon the fields and the gardens. Fruit-trees are not wanting, certainly, north of the Alps. The apple, the pear, and the prune are important in the economy both of man and of nature, but they are far less numerous in Switzerland and Northern France than are the trees I have mentioned in Southern Europe, both because they are in general less remunerative, and because the climate, in higher latitudes, does not permit the free introduction of shade trees into grounds occupied for agricultural purposes.*

---

* The walnut, the chestnut, the apple, and the pear are common to the border between the countries I have mentioned, but the range of the other trees is bounded by the Alps, and by a well-defined and sharply drawn line to the west of those mountains. From some peculiarity in the sky of Europe, cultivated plants will thrive, in Northern Italy, in Southern France, and even in Switzerland, under a depth of shade where no crop, not even grass, worth harvesting, would grow in the United States with an equally high summer temperature. Hence the cultivation of all these trees is practicable in Europe to a greater extent than would be supposed reconcilable with the interests of agriculture. Some idea of the importance of the olive orchards may be formed from the fact that Sicily alone, an island scarcely exceeding 10,000 square miles in area, of which one-third at least is absolutely barren, has exported to the single port of Marseilles more than 2,000,000 pounds weight of olive-oil per year, for the last thirty years.

According to Cosimo Ridolfi, *Lezioni Orali*, vol. ii., p. 340, in a favorable soil and climate the average yield of oil from poorly manured trees, which compose the great majority, is six English pounds, while with the best cultivation it

The multitude of species, intermixed as they are in their spontaneous growth, gives the American forest landscape a variety of aspect not often seen in the woods of Europe, and the gorgeous tints, which nature repeats from the dying dolphin to paint the falling leaf of the American maples, oaks, and ash trees, clothe the hillsides and fringe the water-courses with a rainbow splendor of foliage, unsurpassed by the brightest groupings of the tropical flora. It must be confessed, however, that both the northern and the southern declivities of the Alps exhibit a nearer approximation to this rich and multifarious coloring of autumnal vegetation than most American travellers in Europe are willing to allow; and, besides, the small deciduous shrubs which often carpet the forest-glades of these mountains are dyed with a ruddy and orange glow, which, in the distant landscape, is no mean substitute for the scarlet and crimson and gold and amber of the transatlantic woodland.*

I admit, though not without reluctance, that the forest-trees

---

rises to twenty-three pounds. The annual production of olive-oil in the whole of Italy is estimated at upwards of 850,000,000 pounds, and if we allow twelve pounds to the tree, we have something more than 70,000,000 trees. The real number of trees is, however, much greater than this estimate, for in Tuscany and many other parts of Italy the average yield of oil per tree does not exceed two pounds, and there are many millions of young trees not yet in bearing. Probably we shall not exaggerate if we estimate the olive trees of Italy at 100,000,000, and as there are about a hundred trees to the acre, the quantity of land devoted to the cultivation of the olive may be taken at a million acres. Although olive-oil is much used in cookery in Italy, lard is preferred as more nutritious. Much American lard is exported to South-eastern Italy, and olive-oil is imported in return.

* The most gorgeous autumnal coloring I have observed in the vegetation of Europe has been in the valleys of the Durance and its tributaries in Dauphiny. I must admit that neither in variety nor in purity and brilliancy of tint, does this coloring fall much, if at all, short of that of the New England woods. But there is this difference: in Dauphiny, it is only in small shrubs that this rich painting is seen, while in North America the foliage of large trees is dyed in full splendor. Hence the American woodland has fewer broken lights and more of what painters call breadth of coloring. Besides this, the arrangement of the leafage in large globular or conical masses, affords a wider scale of light and shade, thus aiding now the gradation now the contrast of tints, and gives

of Central and Southern Europe have a great advantage over our own in the corresponding latitudes, in density of foliage as well as in depth of color and persistence of the leaves in deciduous species. An American, who, after a long absence from the United States, returns in the full height of summer, is painfully surprised at the thinness and poverty of the leafage even of the trees which he had habitually regarded as specially umbrageous, and he must wait for the autumnal frosts before he can recover his partiality for the glories of his native woods.

None of our north-eastern evergreens resemble the umbrella pine sufficiently to be a fair object of comparison with it. A cedar, very common above the Highlands on the Hudson, and elsewhere, is extremely like the cypress, straight, slender, with erect, compressed ramification, and feathered to the ground, but its foliage is neither so dark nor so dense, the tree does not attain the majestic height of the cypress, nor has it the lithe flexibility of that tree.* In mere shape, the Lombardy poplar nearly resembles this latter, but it is almost a profanation to compare the two, especially when they are agitated by the wind; for under such circumstances, the one is the most

---

the American October landscape a softer and more harmonious tone than marks the humble shrubbery of the forest hillsides of Dauphiny.

Thoreau—who was not, like some very celebrated landscape critics of the present day, an outside spectator of the action and products of natural forces, but, in the old religious sense, an *observer* of organic nature, living, more than almost any other descriptive writer, among and with her children—has a very eloquent paper on the "Autumnal Tints" of the New England landscape.—See his *Excursions*, pp. 215 *et seqq.*

Few men have personally noticed so many facts in natural history accessible to unscientific observation as Thoreau, and yet he had never seen that very common and striking spectacle, the phosphorescence of decaying wood, until, in the latter years of his life, it caught his attention in a bivouac in the forests of Maine. He seems to have been more excited by this phenomenon than by any other described in his works. It must be a capacious eye that takes in all the visible facts in the history of the most familiar natural object.—*The Maine Woods*, p. 184.

* The cold winter, or rather spring, of 1872 proved fatal to many cypresses as well as olive trees in the Val d'Arno. The cypress, therefore, could be introduced only into California and our Southern States.

While the American forest flora has made large contributions to that of Europe, comparatively few European trees have been naturalized in the United States, and as a general rule the indigenous trees of Europe do not succeed well in our climate. The European mountain-ash—which in beauty, dimensions, and healthfulness of growth is superior to our own *—the horse-chestnut, and the abele, or silver poplar, are valuable additions to the ornamental trees of North America. The Swiss arve or zirbelkiefer, *Pinus cembra*, which yields a well-flavored edible seed and furnishes excellent wood for carving, the umbrella-pine, † which also bears a seed agreeable to the taste, and which, from the color of its foliage and the beautiful form of its dome-like crown, is among the most elegant of trees, the white birch of Central Europe, with its pendulous branches almost rivalling those of the weeping willow in length, flexibility, and gracefulness of fall, and, especially, the "cypresse funerall," might be introduced into the United States with great advantage to the landscape. The European beech and chestnut furnish timber of far better quality than that of their American congeners. The fruit of the European chestnut, though inferior to the American in sweetness and flavor, is

---

ous in the Old World, even in the case of trees not generally receiving special care. This multiplication of varieties is no doubt a result, though not a foreseen or intended one, of human action; for the ordinary operations of European forest economy expose young trees to different conditions from those presented by nature, and new conditions produce new forms. All European woods, except in the remote North, even if not technically artificial forests, acquire a more or less artificial character from the governing hand of man, and the effect of this interference is seen in the constant deviation of trees from the original type. The holly, for example, even when growing as absolutely wild as any tree can ever grow in countries long occupied by man, produces numerous varieties, and twenty or thirty such, not to mention intermediate shades, are described and named as recognizably different, in treatises on the forest-trees of Europe.

* In the Northern Tyrol mountain-ashes fifteen inches in diameter are not uncommon. The berries are distilled with grain to flavor the spirit.

† The mountain ranges of our extreme West produce a pine closely resembling the European umbrella-pine.

larger, and is an important article of diet among the French and Italian peasantry. The walnut of Europe, though not equal to some of the American species in beauty of growth or of wood, or to others in strength and elasticity of fibre, is valuable for its timber and its oil.* The maritine pine, which has proved of such immense use in fixing drifting sands in France, may perhaps be better adapted to this purpose than any of the pines of the New World, and it is of great importance for its turpentine, resin, and tar. The épicéa, or common fir, *Abies picea*, *Abies excelsa*, *Picea excelsa*, abundant in the mountains of France and the contiguous country, is known for its product, Burgundy pitch, and, as it flourishes in a greater variety of soil and climate than almost any other spike-leaved tree, it might be well worth transplantation.* The cork oak has been introduced into California and some other parts of the United States, I believe, and would undoubtedly thrive in the Southern section of the Union.†

---

* The walnut is a more valuable tree than is generally supposed. It yields one-third of the oil produced in France, and in this respect occupies an intermediate position between the olive of the south and the oleaginous seeds of the north. A hectare (about two and a half acres) will produce nuts to the value of five hundred francs a year, which cost nothing but the gathering. Unfortunately, its maturity must be long waited for, and more nut-trees are felled than planted. The demand for its wood in cabinet-work is the principal cause of its destruction. See LAVERGNE, *Économie Rurale de la France*, p. 253.

According to Cosimo Ridolfi (Lezioni Orali, ii., p. 424), France obtains three times as much oil from the walnut as from the olive, and nearly as much as from all oleaginous seeds together. He states that the walnut bears nuts at the age of twenty years, and yields its maximum product at seventy, and that a hectare of ground, with thirty trees, or twelve to the acre, is equal to a capital of twenty-five hundred francs.

The nut of this tree is known in the United States as the "English walnut." The fruit and the wood much resemble those of the American black walnut, *Juglans nigra*, but for cabinet-work the American is the more beautiful material, especially when the large knots are employed. The timber of the European species, when straight-grained, and *clear*, or free from knots, is, for ordinary purposes, better than that of the American black walnut, but bears no comparison with the wood of the hickory, when strength combined with elasticity is required, and its nut is very inferior in taste to that of the shagbark, as well as to the butternut, which it somewhat resembles.

"The chestnut is more valuable still, for it produces on a sterile soil, which, without it, would yield only ferns and heaths, an abundant nutriment for man."—LAVERGNE, *Économie Rurale de la France*, p. 253.

I believe the varieties developed by cultivation are less numerous in the walnut than in the chestnut, which latter tree is often grafted in Southern Europe.

The chestnut crop of France was estimated in 1848 at 3,478,000 hectolitres, or 9,877,520 Winchester bushels, and valued at 13,528,000 francs, or more than two million and a half dollars. In Tuscany the annual yield is computed at about 550,000 bushels.

The Tuscan peasants think the flour of the dried chestnut not less nutritious than Indian cornmeal, and it sells at the same price, or about three cents per English pound, in the mountains, and four cents in the towns.

---

* This fir is remarkable for its tendency to cicatrize or heal over its stumps, a property which it possesses in common with some other firs, the maritime pine, and the European larch. When these trees grow in thick clumps, their roots are apt to unite by a species of natural grafting, and if one of them be felled, although its own proper rootlets die, the stump may continue, sometimes for a century, to receive nourishment from the radicles of the surrounding trees, and a dome of wood and bark of considerable thickness be formed over it. The healing is, however, only apparent, for the entire stump, except the outside ring of annual growth, soon dies, and even decays within its covering, without sending out new shoots. See *Monthly Report, Department of Agriculture*, for October, 1872.

† At the age of twelve or fifteen years, the cork-tree is stripped of its outer bark for the first time. This first yield is of inferior quality, and is employed for floats for nets and buoys, or burnt for lampblack. After this, a new layer of cork, an inch or an inch and a quarter in thickness, is formed about once in ten years, and is removed in large sheets without injury to the tree, which lives a hundred and fifty years or more. According to Clavé (p. 252), the annual product of a forest of cork oaks is calculated at about 660 kilogrammes, worth 150 francs, to the hectare, which, deducting expenses, leaves a profit of 100 francs. This is about equal to 250 pound weight, and eight dollars profit to the acre. The cork oaks of the national domain in Algeria cover about 500,000 acres, and are let to individuals at rates which are expected, when the whole is rented, to yield to the state a revenue of about $2,000,000.

George Sand, in the *Histoire de ma Vie*, speaks of the cork-forests in Southern France as among the most profitable of rural possessions, and states, what I do not remember to have seen noticed elsewhere, that Russia is the best customer for cork. The large sheets taken from the trees are slit into thin plates, and used to line the walls of apartments in that cold climate. On the cultivation and management of the cork oak, see *Des Incendies et de la culture du Chêne-liège*, in *Revue des Eaux et Forêts* for February, 1869.

In the walnut, the chestnut, the cork oak, the mulberry, the olive, the orange, the lemon, the fig, and the multitude of other trees which, by their fruit, or by other products, yield an annual revenue, nature has provided Southern Europe with a partial compensation for the loss of the native forest. It is true that these trees, planted as most of them are at such distances as to admit of cultivation, or of the growth of grass among them, are but an inadequate substitute for the thick and shady wood; but they perform to a certain extent the same offices of absorption and transpiration, they shade the surface of the ground, they serve to break the force of the wind, and on many a steep declivity, many a bleak and barren hillside, the chestnut binds the soil together with its roots, and prevents tons of earth and gravel from washing down upon the fields and the gardens. Fruit-trees are not wanting, certainly, north of the Alps. The apple, the pear, and the prune are important in the economy both of man and of nature, but they are far less numerous in Switzerland and Northern France than are the trees I have mentioned in Southern Europe, both because they are in general less remunerative, and because the climate, in higher latitudes, does not permit the free introduction of shade trees into grounds occupied for agricultural purposes.*

---

* The walnut, the chestnut, the apple, and the pear are common to the border between the countries I have mentioned, but the range of the other trees is bounded by the Alps, and by a well-defined and sharply drawn line to the west of those mountains. From some peculiarity in the sky of Europe, cultivated plants will thrive, in Northern Italy, in Southern France, and even in Switzerland, under a depth of shade where no crop, not even grass, worth harvesting, would grow in the United States with an equally high summer temperature. Hence the cultivation of all these trees is practicable in Europe to a greater extent than would be supposed reconcilable with the interests of agriculture. Some idea of the importance of the olive orchards may be formed from the fact that Sicily alone, an island scarcely exceeding 10,000 square miles in area, of which one-third at least is absolutely barren, has exported to the single port of Marseilles more than 2,000,000 pounds weight of olive-oil per year, for the last thirty years.

According to Cosimo Ridolfi, *Lezioni Orali*, vol. ii., p. 340, in a favorable soil and climate the average yield of oil from poorly manured trees, which compose the great majority, is six English pounds, while with the best cultivation it

The multitude of species, intermixed as they are in their spontaneous growth, gives the American forest landscape a variety of aspect not often seen in the woods of Europe, and the gorgeous tints, which nature repeats from the dying dolphin to paint the falling leaf of the American maples, oaks, and ash trees, clothe the hillsides and fringe the water-courses with a rainbow splendor of foliage, unsurpassed by the brightest groupings of the tropical flora. It must be confessed, however, that both the northern and the southern declivities of the Alps exhibit a nearer approximation to this rich and multifarious coloring of autumnal vegetation than most American travellers in Europe are willing to allow; and, besides, the small deciduous shrubs which often carpet the forest-glades of these mountains are dyed with a ruddy and orange glow, which, in the distant landscape, is no mean substitute for the scarlet and crimson and gold and amber of the transatlantic woodland.*

I admit, though not without reluctance, that the forest-trees

---

rises to twenty-three pounds. The annual production of olive-oil in the whole of Italy is estimated at upwards of 850,000,000 pounds, and if we allow twelve pounds to the tree, we have something more than 70,000,000 trees. The real number of trees is, however, much greater than this estimate, for in Tuscany and many other parts of Italy the average yield of oil per tree does not exceed two pounds, and there are many millions of young trees not yet in bearing. Probably we shall not exaggerate if we estimate the olive trees of Italy at 100,000,000, and as there are about a hundred trees to the acre, the quantity of land devoted to the cultivation of the olive may be taken at a million acres. Although olive-oil is much used in cookery in Italy, lard is preferred as more nutritious. Much American lard is exported to South-eastern Italy, and olive-oil is imported in return.

* The most gorgeous autumnal coloring I have observed in the vegetation of Europe has been in the valleys of the Durance and its tributaries in Dauphiny. I must admit that neither in variety nor in purity and brilliancy of tint, does this coloring fall much, if at all, short of that of the New England woods. But there is this difference: in Dauphiny, it is only in small shrubs that this rich painting is seen, while in North America the foliage of large trees is dyed in full splendor. Hence the American woodland has fewer broken lights and more of what painters call breadth of coloring. Besides this, the arrangement of the leafage in large globular or conical masses, affords a wider scale of light and shade, thus aiding now the gradation now the contrast of tints, and gives

of Central and Southern Europe have a great advantage over our own in the corresponding latitudes, in density of foliage as well as in depth of color and persistence of the leaves in deciduous species. An American, who, after a long absence from the United States, returns in the full height of summer, is painfully surprised at the thinness and poverty of the leafage even of the trees which he had habitually regarded as specially umbrageous, and he must wait for the autumnal frosts before he can recover his partiality for the glories of his native woods.

None of our north-eastern evergreens resemble the umbrella pine sufficiently to be a fair object of comparison with it. A cedar, very common above the Highlands on the Hudson, and elsewhere, is extremely like the cypress, straight, slender, with erect, compressed ramification, and feathered to the ground, but its foliage is neither so dark nor so dense, the tree does not attain the majestic height of the cypress, nor has it the lithe flexibility of that tree.* In mere shape, the Lombardy poplar nearly resembles this latter, but it is almost a profanation to compare the two, especially when they are agitated by the wind; for under such circumstances, the one is the most

---

the American October landscape a softer and more harmonious tone than marks the humble shrubbery of the forest hillsides of Dauphiny.

Thoreau—who was not, like some very celebrated landscape critics of the present day, an outside spectator of the action and products of natural forces, but, in the old religious sense, an *observer* of organic nature, living, more than almost any other descriptive writer, among and with her children—has a very eloquent paper on the "Autumnal Tints" of the New England landscape.—See his *Excursions*, pp. 215 *et seqq.*

Few men have personally noticed so many facts in natural history accessible to unscientific observation as Thoreau, and yet he had never seen that very common and striking spectacle, the phosphorescence of decaying wood, until, in the latter years of his life, it caught his attention in a bivouac in the forests of Maine. He seems to have been more excited by this phenomenon than by any other described in his works. It must be a capacious eye that takes in all the visible facts in the history of the most familiar natural object.—*The Maine Woods*, p. 184.

* The cold winter, or rather spring, of 1872 proved fatal to many cypresses as well as olive trees in the Val d'Arno. The cypress, therefore, could be introduced only into California and our Southern States.

majestic, the other the most ungraceful, or—if I may apply such an expression to anything but human affectation of movement—the most awkward of trees. The poplar trembles before the blast, flutters, struggles wildly, dishevels its foliage, gropes around with its feeble branches, and hisses as in impotent passion. The cypress gathers its limbs still more closely to its stem, bows a gracious salute rather than an humble obeisance to the tempest, bends to the wind with an elasticity that assures you of its prompt return to its regal attitude, and sends from its thick leaflets a murmur like the roar of the far-off ocean.

The cypress and the umbrella-pine are not merely conventional types of the Italian landscape. They are essential elements in a field of rural beauty which can be seen in perfection only in the basin of the Mediterranean, and they are as characteristic of this class of scenery as is the date-palm of the oases of the Eastern desert. There is however, this difference: a single cypress or pine is often enough to shed beauty over a wide area; the palm is a social tree, and its beauty is not so much that of the individual as of the group.* The frequency of the cypress and the pine—combined with the fact that the other trees of Southern Europe which most interest a stranger from the north, the orange and the lemon, the cork oak, the ilex, the myrtle, and the laurel, are evergreens—goes far to explain the beauty of the winter scenery of Italy. Indeed, it is only in the winter that a tourist who confines himself to wheel-carriages and high roads can acquire any notion of the face of the earth, and form any proper geographical image of that country. At other seasons, not high walls only, but equally impervious hedges, and now, unhappily, acacias thickly planted along the railway routes, confine the view so completely, that the arch of a tunnel, or a night-cap over the traveller's eyes, is scarcely a more effectual obstacle to the gratification of his curiosity.*

---

* European poets, whose knowledge of the date-palm is not founded on personal observation, often describe its trunk as not only slender, but particularly *straight*. Nothing can be farther from the truth. When the Orientals compare the form of a beautiful girl to the stem of the palm, they do not represent it as rigidly straight, but on the contrary as made up of graceful curves, which seem less like permanent outlines than like flowing motion. In a palm grove, the trunks, so far from standing planted upright like the candles of a chandelier, bend in a vast variety of curves, now leaning towards, now diverging from, now crossing, each other, and among a hundred you will hardly see two whose axes are parallel.

The Forest does not furnish Food for Man.

In a region absolutely covered with trees, human life could not long be sustained, for want of animal and vegetable food. The depths of the forest seldom furnish either bulb or fruit suited to the nourishment of man; and the fowls and beasts on which he feeds are scarcely seen except upon the margin of the wood, for here only grow the shrubs and grasses, and here only are found the seeds and insects, which form the sustenance of the non-carnivorous birds and quadrupeds.†

---

* Besides this, in a country so diversified in surface as Italy, with the exception of the champaign region drained by the Po, every new field of view requires either an extraordinary *coup d'œil* in the spectator, or a long study, in order to master its relief, its plans, its salient and retreating angles. In summer, except of course in the bare mountains, the universal greenery confounds light and shade, distance and foreground; and though the impression upon a traveller, who journeys for the sake of "sensations," may be strengthened by the mysterious annihilation of all standards for the measurement of space, yet the superior intelligibility of the winter scenery of Italy is more profitable to those who see with a view to analyze.

† Clavé, as well as many earlier writers, supposes that primitive man derived his nutriment from the spontaneous productions of the wood. "It is to the forests," says he, "that man was first indebted for the means of subsistence. Exposed alone, without defence, to the rigor of the seasons, as well as to the attacks of animals stronger and swifter than himself, he found in them his first shelter, drew from them his first weapons. In the first period of humanity, they provided for all his wants: they furnished him wood for warmth, fruits for food, garments to cover his nakedness, arms for his defence."—*Études sur l'Économie Forestière*, p. 13.

But the history of savage life, as far as it is known to us, presents man in that condition as inhabiting only the borders of the forest and the open

First Removal of the Forest.

When multiplying man had filled the open grounds along the margins of the rivers, the lakes, and the sea, and sufficiently peopled the natural meadows and savannas of the interior, where such existed, he could find room for expansion and further growth only by the removal of a portion of the forest that hemmed him in. The destruction of the woods, then, was man's first geographical conquest, his first violation of the harmonies of inanimate nature.

---

grounds that skirt the waters and the woods, and in finding only there the elements which make up his daily bread. The villages of the North American Indians were upon the shores of rivers and lakes, and their weapons and other relics are found only in the narrow open grounds which they had burned over and cultivated, or in the margin of the woods around their location.

Except upon the banks of rivers or of lakes, the woods of the interior of North America, far from the habitations of man, are almost destitute of animal life. Dr. Newberry, describing the vast forests of the yellow pine of the West, *Pinus ponderosa*, remarks: "In the arid and desert regions of the interior basin, we made whole days' marches in forests of yellow pine, of which neither the monotony was broken by other forms of vegetation, nor its stillness by the flutter of a bird or the hum of an insect."—*Pacific Railroad Report*, vol. vi., 1857. Dr. Newberry's *Report on Botany*, p. 37.

Cheadle and Milton's *North-west Passage* confirms these statements. Valvasor says, in a paragraph already quoted, "In my many journeys through this valley, I did never have sight of so much as a single bird."

The wild fruit and nut trees, the Canada plum, the cherries, the many species of walnut, the butternut, the hazel, yield very little, frequently nothing, so long as they grow in the woods; and it is only when the trees around them are cut down, or when they grow in pastures, that they become productive. The berries, too—the strawberry, the blackberry, the raspberry, the whortleberry, scarcely bear fruit at all except in cleared ground.

The native forests of the tropics are as unproductive of human aliment as the less luxuriant woods of the temperate zone. In Strain's unfortunate expedition across the great American isthmus, where the journey lay principally through thick woods, several of the party died of starvation, and for many days the survivors were forced to subsist on the scantiest supplies of unnutritious vegetables perhaps never before employed for food by man. See the interesting account of that expedition in *Harper's Magazine* for March, April, and May, 1856.

Primitive man had little occasion to fell trees for fuel, or for the construction of dwellings, boats, and the implements of his rude agriculture and handicrafts. Windfalls would furnish a thin population with a sufficient supply of such material, and if occasionally a growing tree was cut, the injury to the forest would be too insignificant to be at all appreciable.

The accidental escape and spread of fire, or, possibly, the combustion of forests by lightning, must have first suggested the advantages to be derived from the removal of too abundant and extensive woods, and, at the same time, have pointed out a means by which a large tract of surface could readily be cleared of much of this natural incumbrance. As soon as agriculture had commenced at all, it would be observed that the growth of cultivated plants, as well as of many species of wild vegetation, was particularly rapid and luxuriant on soils which had been burned over, and thus a new stimulus would be given to the practice of destroying the woods by fire, as a means of both extending the open grounds, and making the acquisition of a yet more productive soil. After a few harvests had exhausted the first rank fertility of the virgin mould, or when weeds and briers and the sprouting roots of the trees had begun to choke the crops of the half-subdued soil, the ground would be abandoned for new fields won from the forest by the same means, and the deserted plain or hillock would soon clothe itself anew with shrubs and trees, to be again subjected to the same destructive process, and again surrendered to the restorative powers of vegetable nature.* This rude economy would be continued for generations, and, wasteful as it is, is still largely pursued in Northern Sweden, Swedish Lapland, and sometimes even in France and the United States.*

---

* In many parts of the North American States, the first white settlers found extensive tracts of thin woods, of a very park-like character, called "oak-openings," from the predominance of different species of that tree upon them. These were the semi-artificial pasture-grounds of the Indians, brought into that state, and so kept, by partial clearing, and by the annual burning of the grass. The object of this operation was to attract the deer to the fresh herbage which sprang up after the fire. The oaks bore the annual scorching at least for a certain time; but if it had been indefinitely continued, they would very probably have been destroyed at last. The soil would have then been much in the prairie condition, and would have needed nothing but grazing for

Principal Causes of the Destruction of the Forest.

The needs of agriculture are the most familiar cause of the destruction of the forest in new countries; for not only does an increasing population demand additional acres to grow the vegetables which feed it and its domestic animals, but the slovenly husbandry of the border settler soon exhausts the luxuriance of his first fields, and compels him to remove his household gods to a fresher soil. The extent of cleared ground required for agricultural use depends very much on the number and kinds of the cattle bred. We have seen, in a former chapter, that, in the United States, the domestic quadrupeds amount to more than a hundred millions, or nearly three times the number of the human population of the Union. In many of the

---

a long succession of years to make the resemblance perfect. That the annual fires alone occasioned the peculiar character of the oak-openings, is proved by the fact that as soon as the Indians had left the country, young trees of many species sprang up and grew luxuriantly upon them. See a very interesting account of the oak-openings in Dwight's *Travels*, iv., pp. 58–63.

* The practice of burning over woodland, at once to clear and manure the ground, is called in Swedish *svedjande*, a participial noun from the verb *att svedja*, to burn over. Though used in Sweden as a preparation for crops of rye or other grain, it is employed in Lapland more frequently to secure an abundant growth of pasturage, which follows in two or three years after the fire; and it is sometimes resorted to as a mode of driving the Laplanders and their reindeer from the vicinity of the Swedish backwoodsman's grass-grounds and hay-stacks, to which they are dangerous neighbors. The forest, indeed, rapidly recovers itself, but it is a generation or more before the reindeer-moss grows again. When the forest consists of pine, *tall*, the ground, instead of being rendered fertile by this process, becomes hopelessly barren, and for a long time afterwards produces nothing but weeds and briers.—Læstadius, *Om Uppodlingar i Lappmarken*, p. 15. See also Schubert, *Resa i Sverge*, ii., p. 375.

In some parts of France this practice is so general that Clavé says: "In the department of Ardennes it (*le sartage*) is the basis of agriculture."

Western States, the swine subsist more or less on acorns, nuts, and other products of the woods, and the prairies, or natural meadows of the Mississippi valley, yield a large amount of food for beast, as well as for man. With these exceptions, all this vast army of quadrupeds is fed wholly on grass, grain, pulse, and roots grown on soil reclaimed from the forest by European settlers. It is true that the flesh of domestic quadrupeds enters very largely into the aliment of the American people, and greatly reduces the quantity of vegetable nutriment which they would otherwise consume, so that a smaller amount of agricultural product is required for immediate human food, and, of course, a smaller extent of cleared land is needed for the growth of that product, than if no domestic animals existed. But the flesh of the horse, the ass, and the mule is not consumed by man, and the sheep is reared rather for its fleece than for food. Besides this, the ground required to produce the grass and grain consumed in rearing and fattening a grazing quadruped, would yield a far larger amount of nutriment, if devoted to the growing of breadstuffs, than is furnished by his flesh; and, upon the whole, whatever advantages may be reaped from the breeding of domestic cattle, it is plain that the cleared land devoted to their sustenance in the originally wooded part of the United States, after deducting a quantity sufficient to produce an amount of aliment equal to their flesh, still greatly exceeds that cultivated for vegetables, directly consumed by the people of the same regions; or, to express a nearly equivalent idea in other words, the meadow and the pasture, taken together, much exceed the ploughland.*

---

* The two ideas expressed in the text are not exactly equivalent, because, though the consumption of animal food diminishes the amount of vegetable aliment required for human use, yet the animals themselves consume a great quantity of grain and roots grown on ground ploughed and cultivated as regularly and as laboriously as any other.

The 280,000,000 bushels of oats raised in the United States in 1870, and fed to the 7,000,000 horses, the potatoes, the turnips, and the maize employed in fattening the oxen, the sheep, and the swine slaughtered the same year, occupied an extent of ground which, cultivated by hand-labor and with Chinese

Governments and military commanders have at different periods deliberately destroyed forests by fire or the axe, because they afforded a retreat to robbers, outlaws, or enemies, and this was one of the hostile measures practised by both Julius Cæsar and the Gauls in the Roman war of conquest against that people. It was also resorted to in the Mediterranean provinces of France, then much infested by robbers and deserters, as late as the reign of Napoleon I., and is said to have been employed by the early American colonists in their exterminating wars with the native Indians.[*]

In the Middle Ages, as well as in earlier and later centuries, attempts have been made to protect the woods by law,[†] as

---

industry and skill, would probably have produced a quantity of vegetable food equal in alimentary power to the flesh of the quadrupeds killed for domestic use. Hence, so far as the naked question of *amount* of aliment is concerned, the meadows and the pastures might as well have remained in the forest condition. It must, however, be borne in mind that animal labor, if not a necessary, is probably an economical, force in agricultural occupations, and that without animal manure many branches of husbandry could hardly be carried on at all. At the same time, the introduction of machinery into rural industry, and of artificial, mineral, and fossil manures, is working great revolutions, and we may find at some future day that the ox is no longer necessary as a help to the farmer.

[*] For many instances of this sort, see MAURY, *Les Forêts de la Gaule*, pp. 3–5, and BECQUEREL, *Des Climats*, etc., pp. 301–303. In 1664 the Swedes made an incursion into Jutland and felled a considerable extent of forest. After they retired, a survey of the damage was had, and the report is still extant. The number of trees cut was found to be 120,000, and as an account was taken of the numbers of each species of tree, the document is of much interest in the history of the forest, as showing the relative proportions between the different trees which at that time composed the wood. See VAUPELL, *Bögens Indvandring*, p. 35, and *Notes*, p. 55.

[†] Stanley, quoting Selden, *De Jure Naturali*, lib. vi., and Fabricius, *Cod. Pseudap.*, V. T., i. 874, mentions a noteworthy Hebrew tradition of uncertain date, but unquestionably very ancient, which is one of the oldest proofs of a public respect for the woods.

"A Hebrew tradition attributes to Joshua ten statutes, containing precise regulations for the protection of the property of every tribe and of every head of a family against irregular depredations. Small quadrupeds were allowed to pasture in dense woods, not in thin ones; but no animal could feed in any forest without the consent of the proprietor of the soil. Every Hebrew might necessary for the breeding of deer, wild boars, and other game, or for the more reasonable purpose of furnishing a supply of building timber and fuel for future generations. It was reserved for more advanced ages to appreciate the geographical importance of the woods, and it is only in the most recent times, only in a few countries of Europe, that the general destruction of the forests has been recognized as the most potent among the many causes of the physical deterioration of the earth.*

Royal Forests and Game Laws.

The French authors I have quoted, as well as many other writers of the same nation, refer to the French Revolution as having given a new impulse to destructive causes which were already threatening the total extermination of the woods.† The general crusade against the forests, which accompanied that important event, is to be ascribed, in a considerable degree, to political re-

---

pick up fallen boughs and twigs, but was not permitted to cut them. Trees might be pruned for the trimmings, with the exception of the olive and other fruit-trees, and provided there was sufficient shade in the place."—*Lectures on the History of the Jewish Church*, part i., p. 271.

Alfred Maury mentions several provisions taken from the laws of the Indian legislator Manu, on the same subject.—*Les Forêts de la Gaule*, p. 9.

The very ancient Tables of Heraclea contain provisions for the protection of woods, but whether these referred only to sacred groves, to public forests, or to leased lands, is not clear.

* We must perhaps make an exception in favor of the Emperor Constantine, who commenced the magnificent series of aqueducts and cisterns which still supply Constantinople with water, and enacted strict laws for the protection of the forest of Belgrade, in which rise the springs that feed the aqueducts. See an article by Mr. H. A. Homes on the *Water-Supply of Constantinople* in the *Albany Argus* of June 6, 1872.

† Religious intolerance had produced similar effects in France at an earlier period. "The revocation of the edict of Nantes and the dragonnades occasioned the sale of the forests of the unhappy Protestants, who fled to seek in foreign lands the liberty of conscience which was refused to them in France. The forests were soon felled by the purchasers, and the soil in part brought under cultivation."—BECQUEREL, *Des Climats*, etc., p. 303.

sentments. The forest codes of the mediæval kings, and the local "coutumes" of feudalism, contained many severe and even inhuman provisions, adopted rather for the preservation of game than from any enlightened views of the more important functions of the woods. Ordericus Vitalis informs us that William the Conqueror destroyed sixty parishes and drove out their inhabitants, in order that he might turn their lands into a forest,[*] to be reserved as a hunting-ground for himself and his posterity, and he punished with death the killing of a deer, wild boar, or even a hare. His successor, William Rufus, according to the *Histoire des Ducs de Normandie et des Rois d'Angleterre*, p. 67, "was hunting one day in a new forest, which he had caused to be made out of eighteen parishes that he had destroyed, when, by mischance, he was killed by an arrow wherewith Tyreus de Rois [Sir Walter Tyrell] thought to slay a beast, but missed the beast, and slew the king, who was beyond it. And in this very same forest, his brother Richard ran so hard against a tree that he died of it. And men commonly said that these things were because they had so laid waste and taken the said parishes."

These barbarous acts, as Bonnemère observes,[†] were simply the transfer of the customs of the French kings, of their vassals, and even of inferior gentlemen, to conquered England. "The death of a hare," says our author, "was a hanging matter, the murder of a plover a capital crime. Death was inflicted on those who spread nets for pigeons; wretches who had drawn a bow upon a stag were to be tied to the animal alive; and among the seigniors it was a standing excuse for having killed game on forbidden ground, that they aimed at a serf." The feudal lords enforced these codes with unrelenting rigor, and not unfrequently took the law into their own hands. In the time of Louis IX., according to William of Nangis, "three noble children, born in Flanders, who were sojourning at the abbey of St. Nicholas in the Wood, to learn the speech of France, went out into the forest of the abbey, with their bows and iron-headed arrows, to disport them in shooting hares, chased the game, which they had started in the wood of the abbey, into the forest of Enguerrand, lord of Coucy, and were taken by the sergeants which kept the wood. When the fell and pitiless Sir Enguerrand knew this, he had the children straightway hanged without any manner of trial."* The matter being brought to the notice of good King Louis, Sir Enguerrand was summoned to appear, and, finally, after many feudal shifts and dilatory pleas, brought to trial before Louis himself and a special council. Notwithstanding the opposition of the other seigniors, who, it is needless to say, spared no efforts to save a peer, probably not a greater criminal than themselves, the king was much inclined to inflict the punishment of death on the proud baron. "If he believed," said he, "that our Lord would be as well content with hanging as with pardoning, he would hang Sir Enguerrand in spite of all his barons;" but noble and clerical interests unfortunately prevailed. The king was persuaded to inflict a milder retribution, and the murderer was condemned to pay ten thousand livres in coin, and to "build for the souls of the three children two chapels wherein mass should be said every day." * The hope of shortening the purgatorial term of the young persons, by the religious rites to be celebrated in the chapels, was doubtless the consideration which operated most powerfully on the mind of the king; and Europe lost a great example for the sake of a mass.

---

[*] The American reader must be reminded that, in the language of the chase and of the English law, a "forest" is not necessarily a wood. Any large extent of ground, withdrawn from cultivation, reserved for the pleasures of the chase, and allowed to clothe itself with a spontaneous growth, serving as what is technically called "cover" for wild animals, is, in the dialects I have mentioned, a forest. When, therefore, the Norman kings afforested the grounds referred to in the text, it is not to be supposed that they planted them with trees, though the protection afforded to them by the game laws would, if cattle had been kept out, soon have converted them into real woods.

[†] *Histoire des Paysans*, ii., p. 190. The work of Bonnemère is of great value to those who study the history of mediæval Europe from a desire to know its real character, and not in the hope of finding apparent facts to sustain a false and dangerous theory. Bonnemère is one of the few writers who, like Michelet, have been honest enough and bold enough to speak the truth with regard to the relations between the church and the people in the Middle Ages.

---

* It is painful to add that a similar outrage was perpetrated a very few years ago, in one of the European states, by a prince of a family now dethroned. In this case, however, the prince killed the trespasser with his own hand, his sergeants refusing to execute his mandate.

The desolation and depopulation, resulting from the extension of the forest and the enforcement of the game laws, induced several of the French kings to consent to some relaxation of the severity of these latter. Francis I., however, revived their barbarous provisions, and, according to Bonnemère, even so good a monarch as Henry IV. re-enacted them, and "signed the sentence of death upon peasants guilty of having defended their fields against devastation by wild beasts." "A fine of twenty livres," he continues, "was imposed on every one shooting at pigeons, which, at that time, swooped down by thousands upon the new-sown fields and devoured the seed. But let us count even this a progress, for we have seen that the murder of a pigeon had been a capital crime." †

Not only were the slightest trespasses on the forest domain—the cutting of an oxgoad, for instance—severely punished, but game animals were still sacred when they had wandered from

---

* GUILLAUME DE NANGIS, as quoted in the notes to JOINVILLE, *Nouvelle Collection des Mémoires*, etc., par Michaud et Poujoulat, première série, i., p. 335.

Persons acquainted with the character and influence of the mediæval clergy will hardly need to be informed that the ten thousand livres never found their way to the royal exchequer. It was easy to prove to the simple-minded king that, as the profits of sin were a monopoly of the church, he ought not to derive advantage from the commission of a crime by one of his subjects; and the priests were cunning enough both to secure to themselves the amount of the fine, and to extort from Louis large additional grants to carry out the purposes to which they devoted the money. "And though the king did take the moneys," says the chronicler, "he put them not into his treasury, but turned them into good works; for he builded therewith the maison-Dieu of Pontoise, and endowed the same with rents and lands; also the schools and the dormitory of the friars preachers of Paris, and the monastery of the Minorite friars."

† *Histoire des Paysans*, ii., p. 200.

their native precincts and were ravaging the fields of the peasantry. A herd of deer or of wild boars often consumed or trod down a harvest of grain, the sole hope of the year for a whole family; and the simple driving out of such animals from this costly pasturage brought dire vengeance on the head of the rustic, who had endeavored to save his children's bread from their voracity. "At all times," says Paul Louis Courier, speaking in the name of the peasants of Chambord, in the "Simple Discours," "the game has made war upon us. Paris was blockaded eight hundred years by the deer, and its environs, now so rich, so fertile, did not yield bread enough to support the gamekeepers." * The Tiers État declared, in 1789, "the most ter-

---

* The following details from Bonnemère will serve to give a more complete idea of the vexatious and irritating nature of the game laws of France. The officers of the chase went so far as to forbid the pulling up of thistles and weeds, or the mowing of any unenclosed ground before St. John's day (24th June), in order that the nests of game birds might not be disturbed. It was unlawful to fence-in any grounds in the plains where royal residences were situated; thorns were ordered to be planted in all fields of wheat, barley, or oats, to prevent the use of ground-nets for catching the birds which consumed, or were believed to consume, the grain, and it was forbidden to cut or pull stubble before the first of October, lest the partridge and the quail might be deprived of their cover. For destroying the eggs of the quail, a fine of one hundred livres was imposed for the first offence, double that amount for the second, and for the third the culprit was flogged and banished for five years to a distance of six leagues from the forest.—*Histoire des Paysans*, ii., p. 202, text and notes.

Neither these severe penalties, nor any provisions devised by the ingenuity of modern legislation, have been able effectually to repress poaching. "The game laws," says Clavé, "have not delivered us from the poachers, who kill twenty times as much game as the sportsmen. In the forest of Fontainebleau, as in all those belonging to the state, poaching is a very common and a very profitable offence. It is in vain that the gamekeepers are on the alert night and day, they cannot prevent it. Those who follow the trade begin by carefully studying the habits of the game. They will lie motionless on the ground, by the roadside or in thickets, for whole days, watching the paths most frequented by the animals," etc.—*Revue des Deux Mondes*, Mai, 1863, p. 160.

The writer adds many details on this subject, and it appears that, as there are "beggars on horseback" in South America, there are poachers in carriages in France.

rible scourge of agriculture is the abundance of wild game, a consequence of the privileges of the chase; the fields are wasted, the forests ruined, and the vines gnawed down to the roots."

Effects of the French Revolution.

The abrogation of the game laws and of the harsh provisions of the forestal code was one of the earliest measures of the revolutionary government; and the removal of the ancient restrictions on the chase and of the severe penalties imposed on trespassers upon the public forests, was immediately followed by unbridled license in the enjoyment of the newly conceded rights.

In the popular mind the forest was associated with all the abuses of feudalism, and the evils the peasantry had suffered from the legislation which protected both it and the game it sheltered, blinded them to the still greater physical mischiefs which its destruction was to entail upon them. No longer under the safeguard of the law, the crown forests and those of the great lords were attacked with relentless fury, unscrupulously plundered and wantonly laid waste, and even the rights of property in small private woods ceased to be respected.* Various absurd theories, some of which are not even yet exploded, were propagated with regard to the economical advantages of converting the forest into pasture and ploughland, the injurious effects of the woods upon climate, health, facility of internal communication, and the like. Thus resentful memory of the wrongs associated with the forest, popular ignorance, and the cupidity of speculators cunning enough to turn these circumstances to profitable account, combined to hasten the sacrifice of the remaining woods, and a waste was produced which hundreds of years and millions of treasure will hardly repair.

---

* "Whole trees were sacrificed for the most insignificant purposes; the peasants would cut down two firs to make a single pair of wooden shoes."—MICHELET, as quoted by CLAVÉ. *Études*, p. 24.

A similar wastefulness formerly prevailed in Russia, though not from the same cause. It St. Pierre's time, the planks brought to St. Petersburg were not sawn, but hewn with the axe, and a tree furnished but a single plank.

In the era of savage anarchy which followed the beneficent reforms of 1789, economical science was neglected, and statistical details upon the amount of the destruction of woods during that period are wanting. But it is known to have been almost incalculably rapid, and the climatic and financial evils, which elsewhere have been a more gradual effect of this cause, began to make themselves felt in France within three or four years after that memorable epoch.*

Increased Demand for Lumber.

With increasing population and the development of new industries, come new drains upon the forest from the many arts for which wood is the material. The demands of the near and the distant market for this product excite the cupidity of the hardy forester, and a few years of that wild industry of which Springer's "Forest Life and Forest Trees" so vividly depicts the dangers and the triumphs, suffice to rob the most inaccessible glens of their fairest ornaments. The value of timber increases with its dimensions in almost geometrical proportion, and the tallest, most vigorous, and most symmetrical trees fall the first sacrifice. This is a fortunate circumstance for the remainder of the wood; for the impatient lumberman contents himself with felling a few of the best trees, and then hurries on to take his tithe of still virgin groves.

---

* See BECQUEREL, *Mémoire sur les Forêts*, in the *Mém. de l'Académie des Sciences*, t. xxxv., p. 411 *et seqq.*

Similar circumstances produced a like result, though on a far smaller scale, in Italy, at a very recent period. Gallenga says: "The destruction of the majestic timber [between the Vals Sesia and Sessera] dates no farther back than 1848, when, on the first proclamation of the Constitution, the ignorant boor had taken it for granted that all the old social ties would be loosened, and therefore the old forest-laws should be at once set at naught."—*Country Life in Piedmont*, p. 136.

The vast extension of railroads, of manufactures and the mechanical arts, of military armaments, and especially of the commercial fleets and navies of Christendom, within the present century, has incredibly augmented the demand for wood,[*]

---

[*] Let us take the supply of timber for railroad-ties. According to Clavé (p. 248), France had, in 1862, 9,000 kilomètres of railway in operation, 7,000 in construction, half of which is built with a double track. Adding turn-outs and extra tracks at stations, the number of ties required for a single track is stated at 1,200 to the kilomètre, or, as Clavé computes, for the entire network of France, 58,000,000. This number is too large, for 16,000 + 8,000 for the double track halfway = 24,000, and 24,000 × 1,200 = 28,800,000. In an article in the *Revue des Deux Mondes*, July, 1863, Gandy states that 2,000,000 trees had been felled to furnish the ties for the French railroads, and as the ties must be occasionally renewed, and new railways have been constructed since 1863, we may probably double this number.

The United States had in operation on the first of January, 1872, 61,000 miles, or about 97,000 kilomètres, of railroad. Allowing the same proportion as in France, the American railroads required 116,400,000 ties. The Report of the Agricultural Department of the United States for November and December, 1869, estimates the number of ties annually required for our railways at 30,000,000, and supposes that 150,000 acres of the best woodland must be felled to supply this number. This is evidently an error, perhaps a misprint for 15,000. The same authority calculates the annual expenditure of the American railroads for lumber for buildings, repairs, and cars, at $38,000,000, and for locomotive fuel, at the rate of 19,000 cords of wood per day, at $50,000,000.

The walnut trees cut in Italy and France to furnish gunstocks to the American army, during our late civil war, would alone have formed a considerable forest. A single establishment in Northern Italy used twenty-eight thousand large walnut trees for that purpose in the years 1862 and 1863.

The consumption of wood for lucifer matches is enormous, and I have heard of several instances where tracts of pine forest, hundreds and even thousands of acres in extent, have been purchased and felled, solely to supply timber for this purpose. The United States government tax, at one cent per hundred, produces $2,000,000 per year, which shows a manufacture of 20,000,000,000 matches. Allowing nothing for waste, there are about fifty matches to the cubic inch of wood, or 86,400 to the cubic foot, making in all upwards of 230,000 cubic feet, and, as only straight-grained wood, free from knots, can be used for this purpose, the sacrifice of not less than three or four thousand well-grown pines is required for this purpose.

If we add to all this the supply of wood for telegraph-posts, wooden pavements, wooden wall tapestry-paper, shoe-pegs, and even wooden nails, which have lately come into use—not to speak of numerous other recent applications and but for improvements in metallurgy and the working of iron, which have facilitated the substitution of that metal

---

of this material which American ingenuity has devised—we have an amount of consumption, for entirely new purposes, which is really appalling.

Wooden field and garden fences are very generally used in America, and some have estimated the consumption of wood for this purpose as not less than that for architectural uses.

Fully one-half our vast population is lodged in wooden houses, and barns and country out-houses of all descriptions are almost universally of the same material.

The consumption of wood in the United States as fuel for domestic purposes, for charcoal, for brick and lime kilns, for breweries and distilleries, for steamboats, and many other uses, defies computation, and is vastly greater than is employed in Europe for the same ends. For instance, in rural Switzerland, cold as is the winter climate, the whole supply of wood for domestic fires, dairies, breweries, distilleries, brick and lime kilns, fences, furniture, tools, and even house-building and small smitheries, exclusive of the small quantity derived from the trimmings of fruit-trees, grape-vines, and hedges, and from decayed fences and buildings, does not exceed *two hundred and thirty cubic feet*, or less than two cords a year, per household.—See *Bericht über die Untersuchung der Schweiz Hochgebirgswaldungen*, pp. 85–89. In 1789, Arthur Young estimated the annual consumption of firewood by single families in France at from two and a half to ten Paris cords of 134 cubic feet.—*Travels*, vol. ii., chap. xv.

The report of the Commissioners on the Forests of Wisconsin, 1867, allows three cords of wood to each person for household fires alone. Taking families at an average of five persons, we have eight times the amount consumed by an equal number of persons in Switzerland for this and all other purposes to which this material is ordinarily applicable. I do not think the consumption in the North-eastern States is at all less than the calculation for Wisconsin.

Evergreen trees are often destroyed in immense numbers in the United Sates for the purpose of decoration of churches and on other festive occasions. The New York city papers reported that 113,000 young evergreen trees, besides 20,000 yards of small branches twisted into festoons, were sold in the markets of that city, for this use, at Christmas, in 1869. At the Cincinnati Industrial Exhibition of 1872, three miles of evergreen festoons were hung upon the beams and rafters of the "Floral Hall."

Important statistics on the consumption and supply of wood in the United States will be found in a valuable paper by the Rev. Frederick Starr, Jr., in the *Transactions of the Agricultural Society for* ——.

Of course, there is a vast consumption of ligneous material for all these uses in Europe, but it is greatly less than at earlier periods. The waste of wood for wood, the last twenty-five years would have almost stripped Europe of her last remaining tree fit for these uses.*

---

in European carpentry was formerly enormous, the beams of houses being both larger and more numerous than permanence or stability required. In examining the construction of the houses occupied by the eighty families which inhabit the village of Faucigny, in Savoy, in 1854, the forest inspector found that *fifty thousand* trees had been employed in building them. The builders "seemed," says Hudry-Menos, "to have tried to solve the problem of piling upon the walls the largest quantity of timber possible without crushing them."—*Revue des Deux Mondes*, 1st June, 1864, p. 601.

European statistics present comparatively few facts on this subject, of special interest to American readers, but it is worth noting that France employs 1,500,000 cubic feet of oak per year for brandy and wine casks, which is about half her annual consumption of that material; and it is not a wholly insignificant fact that, according to Rentzsch, the quantity of wood used in parts of Germany for small carvings and for children's toys is so large, that the export of such objects from the town of Sonneberg alone, amounted, in 1853, to 60,000 centner, or three thousand tons' weight.—*Der Wald*, p. 68.

In an article in the *Revue des Eaux et Forêts* for November, 1868, it is stated that 200,000 dozens of drums for boys are manufactured per month in Paris. This is equivalent to 28,800,000 per year, for which 56,000,000 drumsticks are required, and the writer supposes that the annual growth of 50,000 acres of woodland would not more than supply the material. In the same article the consumption of matches in France is given at 7,200,000,000, and the quantity of lumber annually required for this manufacture is computed at 80,000 stères, or cubic mètres—evidently an erroneous calculation.

* Besides the substitution of iron for wood, a great saving of consumption of this latter material has been effected by the revival of ancient methods of increasing its durability, and the invention of new processes for the same purpose. The most effectual preservative yet discovered for wood employed on land, is sulphate of copper, a solution of which is introduced into the pores of the wood while green, by soaking, by forcing-pumps, or, most economically, by the simple pressure of a column of the fluid in a small pipe connected with the end of the piece of timber subjected to the treatment. Clavé (*Études Forestières*, pp. 240–249) gives an interesting account of the various processes employed for rendering wood imperishable, and states that railroad-ties injected with sulphate of copper in 1846, were found absolutely unaltered in 1855; and telegraphic posts prepared two years earlier, are now in a state of perfect preservation.

For many purposes, the method of injection is too expensive, and some simpler process is much to be desired. The question of the proper time of felling timber is not settled, and the best modes of air, water, and steam seasoning are not yet fully ascertained. Experiments on these subjects would

I have spoken of the foreign demand for American agricultural products as having occasioned an extension of cultivated ground, which had led to clearing land not required by the necessities of home consumption. But the forest itself has become, so to speak, an article of exportation. England, as we have seen, imported oak and pine from the Baltic ports more than six hundred years ago. She has since drawn largely on the forests of Norway, and for many years has received vast quantities of lumber from her American possessions.

The unparalleled facilities for internal navigation, afforded by the numerous rivers of the present and former British colonial possessions in North America, have proved very fatal to the forests of that continent. Quebec became many years ago a

---

be well worth the patronage of Governments in new countries, where they can be very easily made, without the necessity of much waste of valuable material, and without expensive arrangements for observation.

The practice of stripping living trees of their bark some years before they are felled, is as old as the time of Vitruvius, but is much less followed than it deserves, partly because the timber of trees so treated inclines to crack and split, and partly because it becomes so hard as to be wrought with considerable difficulty.

In America, economy in the consumption of fuel has been much promoted by the substitution of coal for wood, the general use of stoves both for wood and coal, and recently by the employment of anthracite in the furnaces of stationary and locomotive steam-engines. All the objections to the use of anthracite for this latter purpose appear to have been overcome, and the improvements in its combustion have been attended with a great pecuniary saving, and with much advantage to the preservation of the woods.

The employment of coal has produced a great reduction in the consumption of firewood in Paris. In 1815, the supply of firewood for the city required 1,200,000 *stères*, or cubic mètres; in 1859 it had fallen to 501,805, while, in the meantime, the consumption of coal had risen from 600,000 to 4,320,000 metrical quintals. See CLAVÉ, *Études*, p. 212.

In 1869 Paris consumed 951,157 *stères* of firewood, 4,902,414 hectolitres, or more than 13,000,000 bushels, of charcoal, and 6,872,000 metrical quintals, or more than 7,000,000 tons of mineral coal.—*Annuaire de la Revue des Eaux et Forêts* for 1872, p. 26.

The increase in the price of firewood at Paris, within a century, has been comparatively small, while that of timber and of sawed lumber has increased enormously.

centre for a lumber trade, which, in the bulk of its material, and, consequently, in the tonnage required for its transportation, rivalled the commerce of the greatest European cities. Immense rafts were collected at Quebec from the great Lakes, from the Ottawa, and from all the other tributaries which unite to swell the current of the St. Lawrence and help it to struggle against its mighty tides.* Ships, of burden formerly undreamed of, have been built to convey the timber to the markets of Europe, and during the summer months the St. Lawrence is almost as crowded with shipping as the Thames.†

---

* The tide rises at Quebec to the height of twenty-five feet, and when it is aided by a north-east wind, it flows with almost irresistible violence. Rafts containing several hundred thousand cubic feet of timber are often caught by the flood-tide, torn to pieces, and dispersed for miles along the shores.

† One of these, the Baron of Renfrew—so named from one of the titles of the kings of England—built forty or fifty years ago, measured 5,000 tons. They were little else than rafts, being almost solid masses of timber designed to be taken to pieces and sold as lumber on arriving at their port of destination.

The lumber trade at Quebec is still very large. According to an article in the *Revue des Deux Mondes*, that city exported, in 1860, 30,000,000 cubic feet of squared timber, and 400,000,000 square feet of "planches." The thickness of the boards is not stated, but I believe they are generally cut an inch and a quarter thick for the Quebec trade, and as they shrink somewhat in drying, we may estimate ten square for one cubic foot of boards. This gives a total of 70,000,000 cubic feet. The specific gravity of white pine is .554, and the weight of this quantity of lumber, very little of which is thoroughly seasoned, would exceed a million of tons, even supposing it to consist wholly of wood as light as pine.

The London *Times* of Oct. 10, 1871, states the exportation of lumber from Canada to Europe, in 1870, at 200,000,000 cubic feet, and adds that more than three times that quantity was sent from the same province to the United States. A very large proportion of this latter quantity goes to Burlington, Vermont, whence it is distributed to other parts of the Union.

There must, I think, be some error or exaggeration in these figures. Perhaps instead of cubic feet we should read square feet. Two hundred millions of cubic feet of timber would require more than half the entire tonnage of England for its transportation.

I suppose the quantities in the following estimates, from a carefully prepared article in the *St. Louis Republican*, must be understood as meaning square or superficial feet, board measure, allowing a thickness of one inch:

"The lumber trade of Michigan, Wisconsin, and Minnesota, for the year

Effects of Forest Fires.

The operations of the lumberman involve other dangers to the woods besides the loss of the trees felled by him. The narrow clearings around his *shanties* form openings which let in the wind, and thus sometimes occasion the overthrow of thousands of trees, the fall of which dams up small streams, and creates bogs by the spreading of the waters, while the decaying trunks facilitate the multiplication of the insects which breed in dead wood and are, some of them, injurious to living trees. The escape and spread of camp-fires, however, is the most devastating of all the causes of destruction that find their origin in the operations of the lumberman. The proportion of trees fit for industrial uses is small in all primitive woods. Only these fall before the forester's axe, but the fire destroys, almost indiscriminately, every age and every species of tree.* While, then,

---

1869, shows the amount cut as being 2,029,372,255 feet for the State of Michigan, and 317,400,000 feet for the State of Minnesota, and 964,600,000 feet for the State of Wisconsin. This includes the lake shore and the whole State of Wisconsin, which heretofore has been difficult to get a report from. The total amount cut in these States was 3,311,372,255 feet, and that to obtain this quantity there have been shipped 883,032 acres, or 1,380 square miles of pine have been removed. It is calculated that 4,000,000 acres of land still remain unstripped in Michigan, which will yield 15,000,000,000 feet of lumber; while 3,000,000 acres are still standing in Wisconsin, which will yield 11,250,000,000 feet, and that which remains in Minnesota, taking the estimate of a few years since of that which was surveyed and unexplored, after deducting the amount cut the past few years, we find 3,630,000 acres to be the proper estimate of trees now standing which will yield 32,362,500,000 feet of lumber. This makes a total of 15,630,000 acres of pine lands, which remain standing in the above States, that will yield 58,612,500,000 feet of lumber, and it is thought that fifteen or twenty years will be required to cut and send to market the trees now standing."

See also BRYANT, *Forest Trees*, chap. iv.

* Trees differ in their power of resisting the action of forest fires. Different woods vary greatly in combustibility, and even when the bark is scarcely scorched, trees are, partly in consequence of physiological character, and partly from the greater or less depth at which their roots habitually lie below the surface, differently affected by running fires. The white pine, *Pinus*

without fatal injury to the younger growths, the native forest will bear several "cuttings over" in a generation—for the increasing value of lumber brings into use, every four or five years, a quality of timber which had been before rejected as unmarketable—a fire may render the declivity of a mountain unproductive for a century.*

Aside from the destruction of the trees and the laying bare of the soil, and consequently the freer admission of sun, rain, and air to the ground, the fire of itself exerts an important influence on its texture and condition. It cracks and sometimes even pulveri-

---

strobus, as it is the most valuable, is also perhaps the most delicate tree of the American forest, while its congener, the Northern pitch-pine, *Pinus rigida*, is less injured by fire than any other tree of that country. I have heard experienced lumbermen maintain that the growth of this pine was even accelerated by a fire brisk enough to destroy all other trees, and I have myself seen it still flourishing after a conflagration which had left not a green leaf but its own in the wood, and actually throwing out fresh foliage, when the old had been quite burnt off and the bark almost converted into charcoal. The wood of the pitch-pine is of comparatively little value for the joiner, but it is useful for very many purposes. Its rapidity of growth in even poor soils, its hardihood, and its abundant yield of resinous products, entitle it to much more consideration, as a plantation tree, than it has hitherto received in Europe or America.

* Between sixty and seventy years ago, a steep mountain with which I am familiar, composed of metamorphic rock, and at that time covered with a thick coating of soil and a dense primeval forest, was accidentally burnt over. The fire took place in a very dry season, the slope of the mountain was too rapid to retain much water, and the conflagration was of an extraordinarily fierce character, consuming the wood almost entirely, burning the leaves and combustible portion of the mould, and in many places cracking and disintegrating the rock beneath. The rains of the following autumn carried off much of the remaining soil, and the mountain-side was nearly bare of wood for two or three years afterwards. At length a new crop of trees sprang up and grew vigorously, and the mountain is now thickly covered again. But the depth of mould and earth is too small to allow the trees to reach maturity. When they attain to the diameter of about six inches, they uniformly die, and this they will no doubt continue to do until the decay of leaves and wood on the surface, and the decomposition of the subjacent rock, shall have formed, perhaps hundreds of years hence, a stratum of soil thick enough to support a full-grown forest. Under favorable conditions, however, as in the case of the fire of Miramichi, a burnt forest renews itself rapidly and permanently.

zes the rocks and stones upon and near the surface; [*] it consumes a portion of the half-decayed vegetable mould which served to hold its mineral particles together and to retain the water of precipitation, and thus loosens, pulverizes, and dries the earth; it destroys reptiles, insects, and worms, with their eggs, and the seeds of trees and of smaller plants; it supplies, in the ashes which it deposits on the surface, important elements for the growth of a new forest clothing, as well as of the usual objects of agricultural industry; and by the changes thus produced, it fits the ground for the reception of a vegetation different in character from that which had spontaneously covered it. These new conditions help to explain the natural succession of forest crops, so generally observed in all woods cleared by fire and then abandoned. There is no doubt, however, that other influences contribute to the same result, because effects more or less analogous follow when the trees are destroyed by other causes, as by high winds, by the woodman's axe, and even by natural decay.[†]

---

[*] In the burning over of a hill-forest in the Lower Engadine, in September, 1865, the fire was so intense as to shatter and calcine the rocks on the slope, and their fragments were precipitated into the valley below.—*Rivista Forestale del Regno d'Italia*, Ottobre, 1865, p. 474.

[†] The remarkable mounds and other earthworks constructed in the valley of the Ohio and elsewhere in the territory of the United States, by a people apparently more advanced in culture than the modern Indian, were overgrown with a dense clothing of forest when first discovered by the whites. But though the ground where they were erected must have been occupied by a large population for a considerable length of time, and therefore entirely cleared, the trees which grew upon the ancient fortresses and the adjacent lands were not distinguishable in species, or even in dimensions and character of growth, from the neighboring forests, where the soil seemed never to have been disturbed. This apparent exception to the law of change of crop in natural forest growth was ingeniously explained by General Harrison's suggestion, that the lapse of time since the era of the mound-builders was so great as to have embraced several successive generations of trees, and occasioned, by their rotation, a return to the original vegetation.

The successive changes in the spontaneous growth of the forest, as proved by the character of the wood found in bogs, are such as to have suggested the theory of a considerable change of climate during the human period. But

Another evil, sometimes of serious magnitude, which attends the operations of the lumberman, is the injury to the banks of rivers from the practice of floating. I do not here allude to rafts, which, being under the control of those who navigate them, may be so guided as to avoid damage to the shore, but to masts, logs, and other pieces of timber singly entrusted to the streams, to be conveyed by their currents to sawmill ponds,

---

this theory cannot be admitted upon the evidence in question. In fact, the order of succession—for a rotation or alternation is neither proved nor probable—may be made to move in opposite directions in different countries with the same climate and at the same time. Thus in Denmark and in Holland the spike-leaved firs have given place to the broad-leaved beech, while in Northern Germany the process has been reversed, and evergreens have supplanted the oaks and birches of deciduous foliage. The principal determining cause seems to be the influence of light upon the germination of the seeds and the growth of the young tree. In a forest of firs, for instance, the distribution of the light and shade, to the influence of which seeds and shoots are exposed, is by no means the same as in a wood of beeches or of oaks, and hence the growth of different species will be stimulated in the two forests.

When ground is laid bare both of trees and of vegetable mould, and left to the action of unaided and unobstructed nature, she first propagates trees which germinate and grow only under the influence of a full supply of light and air, and then, in succession, other species, according to their ability to bear the shade and their demand for more abundant nutriment. In Northern Europe the larch, the white birch, the aspen, first appear; then follow the maple, the alder, the ash, the fir; then the oak and the linden; and then the beech. The trees called by these respective names in the United States are not specifically the same as their European namesakes, nor are they always even the equivalents of these latter, and therefore the order of succession in America would not be precisely as indicated by the foregoing list, but, so far as is known, it nevertheless very nearly corresponds to it.

It is thought important to encourage the growth of the beech in Denmark and Northern Germany, because it upon the whole yields better returns than other trees, and does not exhaust, but on the contrary enriches, the soil; for by shedding its leaves it returns to it most of the nutriment it has drawn from it, and at the same time furnishes a solvent which aids materially in the decomposition of its mineral constituents.

When the forest is left to itself, the order of succession is constant, and its occasional inversion is always explicable by some human interference. It is curious that the trees which require most light are content with the poorest soils, and *vice versa*. The trees which first appear are also those which propagate themselves farthest to the north. The birch, the larch, and the fir or to convenient places for collecting them into rafts. The lumbermen usually haul the timber to the banks of the rivers in the winter, and when the spring floods swell the streams and break up the ice, they roll the logs into the water, leaving them to float down to their destination. If the transporting stream is too small to furnish a sufficient channel for this rude navigation, it is sometimes dammed up, and the timber collected in the pond thus formed above the dam. When the pond is full, a sluice is opened, or the dam is blown up or otherwise suddenly broken, and the whole mass of lumber above it is hurried down with the rolling flood. Both of these modes of proceeding expose the banks of the rivers employed as channels of flotation to abrasion,[*] and in some of the American States it has been found necessary to protect, by special legislation, the lands through which they flow from the serious injury sometimes received through the practices I have described.[†]

---

bear a severer climate than the oak, the oak than the beech. "These parallelisms," says Vaupell, "are very interesting, because, though they are entirely independent of each other," they all prescribe the same order of succession.—*Bögens Indvandring*, p. 42. See also Berg, *Das Verdrängen der Laubwälder im Nördlichen Deutschland*, 1844. Heyer, *Das Verhalten der Waldbäume gegen Licht und Schatten*, 1852. Staring, *De Bodem van Nederland*, 1856, i., pp. 120–200. Vaupell, *De Danske Skove*, 1863. Knorr, *Studien über die Buchen-Wirthschaft*, 1863. A. Maury, *Les Forêts de la Gaule*, pp. 73, 74, 377, 384.

[*] Caimi states that "a single flotation in the Valtelline, in 1839, caused damages appraised at $250,000."—*Cenni sulla Importanza e Coltura dei Boschi*, p. 65.

[†] Many physicists who have investigated the laws of natural hydraulics maintain that, in consequence of direct obstruction and frictional resistance to the flow of the water of rivers along their banks, there is both an increased rapidity of current and an elevation of the water in the middle of the channel, so that a river presents always a convex surface. Others have thought that the acknowledged greater swiftness of the central current must produce a depression in that part of the stream. The lumbermen affirm that, while rivers are rising, the water is highest in the middle of the channel, and tends to throw floating objects shorewards; while they are falling, it is lowest in the middle, and floating objects incline towards the centre. Logs, they say, rolled into the water during the rise, are very apt to lodge on the banks, while those set afloat during the falling of the waters keep in the current, and are

Restoration of the Forest.

In most countries of Europe—and I fear in many parts of the United States—the woods are already so nearly extirpated, that the mere protection of those which now exist is by no means an adequate security against a great increase of the evils which have already resulted from the diminution of them. Besides this, experience has shown that where the destruction of the woods has been carried beyond a certain point, no coercive legislation can absolutely secure the permanence of the remainder, especially if it is held by private hands. The creation of new forests, therefore, is generally recognized, wherever the subject has received the attention it merits, as an indispensable measure of sound public economy. Enlightened individuals in some European states, the Governments in others, have made extensive plantations, and France, particularly, has now set herself energetically at work to restore the woods in her southern

---

carried without hindrance to their destination, and this law, which has been a matter of familiar observation among woodmen for generations, is now admitted as a scientific truth.

Foresters and lumbermen, like sailors and other persons whose daily occupations bring them into contact, and often into conflict, with great natural forces, have many peculiar opinions, not to say superstitions. In one of these categories we must rank the universal belief of lumbermen, that with a given head of water, and in a given number of hours, a sawmill cuts more lumber by night than by day. Having been personally interested in several sawmills, I have frequently conversed with sawyers on this subject, and have always been assured by them that their uniform experience established the fact that, other things being equal, the action of the machinery of sawmills is more rapid by night than by day. I am sorry—perhaps I ought to be ashamed—to say that my skepticism has been too strong to allow me to avail myself of my opportunities of testing this question by passing a night, watch in hand, counting the strokes of a millsaw. More unprejudiced, and, I must add, very intelligent and credible persons have informed me that they have done so, and found the report of the sawyers abundantly confirmed. A land surveyor, who was also an experienced lumberman, sawyer, and machinist, a good mathematician and an accurate observer, has repeatedly told me that he had very often "timed" sawmills, and found the difference in favor of night-work above thirty per cent. *Sed quære.*

provinces, and thereby to prevent the utter depopulation and waste with which that once fertile soil and genial climate are threatened.

The objects of the restoration of the forest are as multifarious as the motives that have led to its destruction, and as the evils which that destruction has occasioned. It is hoped that the replanting of the mountain slopes, and of bleak and infertile plains, will diminish the frequency and violence of river inundations, prevent the formation of new torrents and check the violence of those already existing, mitigate the extremes of atmospheric temperature, humidity, and precipitation, restore dried-up springs, rivulets, and sources of irrigation, shelter the fields from chilling and from parching winds, arrest the spread of miasmatic effluvia, and, finally, furnish a self-renewing and inexhaustible supply of a material indispensable to so many purposes of domestic comfort, and to the successful exercise of every art of peace, every destructive energy of war.*

The Economy of the Forest.

The legislation of European states upon sylviculture, and the practice of that art, divide themselves into two great branches —the preservation of existing forests, and the creation of new. Although there are in Europe many forests neither planted nor regularly trained by man, yet from the long operation of causes already set forth, what is understood in America and other new countries by the "primitive forest," no longer exists in the territories which were the seats of ancient civilization and empire, except upon a small scale, and in remote and almost inaccessible glens quite out of the reach of ordinary observation. The oldest European woods are indeed native, that is, sprung from self-sown seed, or from the roots of trees which have been felled for human purposes; but their growth has been controlled, in a variety of ways, by man and by domestic animals, and they almost uniformly present more or less of an artificial character and arrangement. Both they and planted forests—which, though certainly not few, are of comparatively recent date in Europe—demand, as well for protection as for promotion of growth, a treatment different in some respects from that which would be suited to the character and wants of the virgin wood.

---

* The preservation of the woods on the former eastern frontier of France, as a kind of natural abattis, was recognized by the Government of that country as an important measure of military defence, though there have been conflicting opinions on the subject.

On this latter branch of the subject, the management of the primitive wood, experience and observation have not yet collected a sufficient stock of facts to serve for the construction of a complete system of this department of sylviculture; but the government of the forest as it exists in France—the different zones and climates of which country present many points of analogy with those of the United States and of some of the British colonies—has been carefully studied, and several manuals of practice have been prepared for the foresters of that empire. I believe the *Cours Élémentaire de Culture des Bois créé à l'École Forestière de Nancy, par M. Lorentz, complété et publié par A. Parade*, with a supplement under the title of *Cours d'Aménagement des Forêts, par Henri Nanquette*, has been generally considered the best of these. The *Études sur l'Économie Forestière, par Jules Clavé*, which I have often quoted, presents a great number of interesting views on this subject, but it is not designed as a practical guide, and it does not profess to be sufficiently specific in its details to serve that purpose.[*] Notwithstanding the difference of conditions between the aboriginal and the trained forest, the judicious observer who aims at the preservation of the former will reap much instruction from the treatises I have cited, and I believe he will be convinced that the sooner a natural wood is brought into the state of an artificially regulated one, the better it is for all the multiplied interests which depend on the wise administration of this branch of public economy.

---

[*] Among more recent manuals may be mentioned: in French, *Les Études de Maître Pierre*, Paris, 1864, 12mo; BAZELAIRE, *Traité de Reboisement*, 2d edition, Paris, 1864; PASTON, *L'Aménagement des Forêts*, Paris, 1867; in English, GREGOR, *Arboriculture*, Edinburgh. 1868; in Italian, SIEMONI'S very valuable *Manuale teorico-pratico d'Arte Forestale*, 2d ediz., Firenze, 1872; the ex-

One consideration bearing on this subject has received less attention than it merits, because most persons interested in such questions have not opportunities for the comparison I refer to. I mean the great general superiority of cultivated timber to that of strictly spontaneous growth. I say *general* superiority, because there are exceptions to the rule. The white pine, *Pinus strobus*, for instance, and other trees of similar character and uses, require, for their perfect growth and best ligneous texture, a density of forest vegetation around them, which protects them from too much agitation by wind, and from the persistence of the lateral branches which fill the wood with knots. A pine which has grown under those conditions possesses a tall, straight stem, admirably fitted for masts and spars, and, at the same time, its wood is almost wholly free from knots, is regular in annular structure, soft and uniform in texture, and, consequently, superior to almost all other timber for joinery. If, while a large pine is spared, the broad-leaved or other smaller trees around it are felled, the swaying of the tree from the action of the wind mechanically produces separations between the layers of annual growth, and greatly diminishes the value of the timber. The same defect is often observed in pines which, from some accident of growth, have much overtopped their fellows in the virgin forest.

The white pine, growing in the fields, or in open glades in the woods, is totally different from the true forest-tree, both in general aspect and in quality of wood. Its stem is much

---

cellent work of CERINI, *Dei Vantaggi di Società, per l'Impianto e Conservazione dei Boschi*, Milano, 1844, 8vo; and the prize essay of MEGUSCHER, *Memoria sui Boschi*, etc., 2d edizione, Milano, 1859, 8vo. Another very important treatise on the uses of the forest, though not a manual of sylviculture, is SCHLEIDEN, *Für Baum und Wald*, Leipzig, 1870.

shorter, its top less tapering, its foliage denser and more inclined to gather into tufts, its branches more numerous and of larger diameter, its wood shows much more distinctly the divisions of annual growth, is of coarser grain, harder and more difficult to work into mitre-joints. Intermixed with the most valuable pines in the American forests, are met many trees of the character I have just described. The lumbermen call them "saplings," and generally regard them as different in species from the true white pine, but botanists are unable to establish a distinction between them, and as they agree in almost all respects with trees grown in the open grounds from known white-pine seedlings, I believe their peculiar character is due to unfavorable circumstances in their early growth. The pine, then, is an exception to the general rule as to the inferiority of the forest to the open-ground tree. The pasture oak and pasture beech, on the contrary, are well known to produce far better timber than those grown in the woods, and there are few trees to which the remark is not equally applicable.[*]

---

[*] It is often laid down as a universal law, that the wood of trees of slow vegetation is superior to that of quick growth. This is one of those commonplaces by which men love to shield themselves from the labor of painstaking observation. It has, in fact, so many exceptions, that it may be doubted whether it is in any sense true. Most of the cedars are slow of growth; but while the timber of some of them is firm and durable, that of others is light, brittle, and perishable. The hemlock-spruce is slower of growth than the pines, but its wood is of very little value. The pasture oak and beech show a breadth of grain—and, of course, an annual increment—twice as great as trees of the same species grown in the woods; and the American locust, *Robinia pseudacacia*, the wood of which is of extreme toughness and durability, is, of all trees indigenous to North-eastern America, by far the most rapid in growth. Some of the species of the Australian *Eucalyptus* furnish wood of remarkable strength and durability, and yet the eucalyptus is surpassed by no known tree in rapidity of growth.

As an illustration of the mutual interdependence of the mechanic arts, I may mention that in Italy, where stone, brick, and plaster are almost the only materials used in architecture, and where the "hollow ware" kitchen implements are of copper or of clay, the ordinary tools for working wood are of a very inferior description, and the locust timber is found too hard for their temper. At the same time the work of the Italian *stipettai*, or cabinet-makers, Another advantage of the artificially regulated forest is, that it admits of such grading of the ground as to favor the retention or discharge of water at will, while the facilities it affords for selecting and duly proportioning, as well as properly spacing, and in felling and removing, from time to time, the trees which compose it, are too obvious to require to be more than hinted at. In conducting these operations, we must have a diligent eye to the requirements of nature, and must remember that a wood is not an arbitrary assemblage of trees to be selected and disposed according to the caprice of its owner. "A forest," says Clavé, "is not, as is often supposed, a simple collection of trees succeeding each other in long perspective, without bond of union, and capable of isolation from each other; it is, on the contrary, a whole, the different parts of which are interdependent upon each other, and it constitutes, so to speak, a true individuality. Every forest has a special character, determined by the form of the surface it grows upon, the kinds of trees that compose it, and the manner in which they are grouped."

The art, or, as the Continental foresters rather ambitiously call it, the science of sylviculture has been so little pursued in England and America, that its nomenclature has not been introduced into the English vocabulary, and it would not be possible to describe its processes with technical propriety of language, without occasionally borrowing a word from the forest

---

and carvers in wood, who take pains to provide themselves with tools of better metal, is wholly unsurpassed in finish and in accuracy of adjustment as well as in taste. When a small quantity of mahogany was brought to England, early in the last century, the cabinet-makers were unable to use it, from the defective temper of their tools, until the demand for furniture from the new wood compelled them to improve the quality of their implements. In America, the cheapness of wood long made it the preferable material for almost all purposes to which it could by any possibility be applied. The mechanical cutlery and artisans' tools of the United States are of admirable temper, finish, and convenience, and no wood is too hard, or otherwise too refractory, to be wrought with great facility, both by hand-tools and by the multitude of ingenious machines which the Americans have invented for this purpose.

literature of France and Germany. A full discussion of the methods of sylviculture would, indeed, be out of place in a work like the present, but the want of conveniently accessible means of information on the subject, in the United States, will justify me in presenting it with somewhat more of detail than would otherwise be pertinent.

The two best known methods of treating already existing forests are those distinguished as the *taillis*, copse or coppice treatment,[*] and the *futaie*, for which I find no English equivalent, but which may not inappropriately be called the *full-growth* system. A *taillis*, copse, or coppice, is a wood composed of shoots from the roots of trees previously cut for fuel and timber. The shoots are thinned out from time to time, and finally cut, either after a fixed number of years, or after the young trees have attained to certain dimensions, their roots being then left to send out a new progeny as before. This is the cheapest method of management, and therefore the best wherever the price of labor and of capital bears a high proportion to that of land and of timber; but it is essentially a wasteful economy.[†] If the woodland is, in the first place, completely cut over, as is found most convenient in practice, the young shoots have neither the shade nor the protection from wind so important to forest growth, and their progress is comparatively slow, while, at the same time, the thick clumps they form choke the seedlings that may have sprouted near them.[*] The evergreens, once cut, do not shoot up again,[†] and the mixed character of the forest—in many respects an important advantage, if not an indispensable condition of growth—is lost;[‡] and besides this,

---

[*] *Copse*, or *coppice*, from the French *couper*, to cut, means properly a wood the trees of which are cut at certain periods of immature growth, and allowed to shoot up again from the roots; but it has come to signify, very commonly, a young wood, grove, or thicket, without reference to its origin, or to its character of a forest crop.

[†] "In America," says Clavé (p. 124, 125), "where there is a vast extent of land almost without pecuniary value, but where labor is dear and the rate of interest high, it is profitable to till a large surface at the least possible cost; *extensive* cultivation is there the most advantageous. In England, France, and Germany, where every corner of soil is occupied, and the least bit of ground is sold at a high price, but where labor and capital are comparatively cheap, it is wisest to employ *intensive* cultivation. . . All the efforts of the cultivator ought to be directed to the obtaining of a given result with the least sacrifice, and there is equally a loss to the commonwealth if the application of improved agricultural processes be neglected where they are advantageous, or if they be employed where they are not required. . . In this point of view, sylviculture must follow the same laws as agriculture, and, like it, be modified according to the economical conditions of different states. In countries abounding in good forests, and thinly peopled, elementary and cheap

---

methods must be pursued; in civilized regions, where a dense population requires that the soil shall be made to produce all it can yield, the regular artificial forest, with all the processes that science teaches, should be cultivated. It would be absurd to apply to the endless woods of Brazil and of Canada the method of the Spessart by "double stages," but not less so in our country, where every yard of ground has a high value, to leave to nature the task of propagating trees, and to content ourselves with cutting, every twenty or twenty-five years, the meagre growths that chance may have produced."

[*] In ordinary coppices, there are few or no seedlings, because the young shoots are cut before they are old enough to mature fertile seed, and this is one of the strongest objections to the system.

[†] It was not long ago stated, upon the evidence of the Government foresters of Greece, and of the queen's gardener, that a large wood has been discovered in Arcadia, consisting of a fir which has the property of sending up both vertical and lateral shoots from the stump of felled trees and forming a new crown. It was at first supposed that this forest grew only on the "mountains," of which the hero of About's most amusing story, *Le Roi des Montagnes*, was "king;" but stumps, with the shoots attached, have been sent to Germany, and recognized by able botanists as true natural products, and the fact must now be considered as established. Daubeny refers to Theophrastus as ascribing this faculty of reproduction to the ἐλάτη or fir, but he does not cite chapter and verse, and I have not been able to find the passage. The same writer mentions a case where an entire forest of the common fir in France had been renewed in this way.—*Trees and Shrubs of the Ancients*, 1865, pp. 27–28. The American Northern pitch possesses the same power in a certain degree.

According to Charles Martins, the cedar of Mount Atlas—which, if no tidentical with the cedar of Lebanon, is closely allied to it—possesses the same power.—*Revue des Deux Mondes*, July 15, 1864, p. 315.

[‡] Natural forests are rarely, if ever, composed of trees of a single species, and experience has shown that oaks and other broad-leaved trees, planted as artificial woods, require to be mixed, or associated with others of different habits.

In the forest of Fontainebleau, "oaks, mingled with beeches in due proporlarge wood of any species cannot be grown in this method, because trees which shoot from decaying stumps and their dying roots, become hollow or otherwise unsound before they acquire their full dimensions. A more fatal objection still, is, that the roots of trees will not bear more than two or three, or at most four cuttings of their shoots before their vitality is exhausted, and the wood can then be restored only by replanting entirely. The period of cutting coppices varies in Europe from fifteen to forty years, according to soil, species, and rapidity of growth.

In the *futaie*, or full-growth system, the trees are allowed to stand as long as they continue in healthy and vigorous growth. This is a shorter period than would be at first supposed, when we consider the advanced age and great dimensions to which, under favorable circumstances, many forest-trees attain in temperate climates. But, as every observing person familiar with the forest is aware, these are exceptional cases, just as are instances of great longevity or of gigantic stature among men. Able vegetable physiologists have maintained that the tree,

---

tion," says Clavé, "may arrive at the age of five or six hundred years in full vigor, and attain dimensions which I have never seen surpassed; when, however, they are wholly unmixed with other trees, they begin to decay and die at the top, at the age of forty or fifty years, like men, old before their time, weary of the world, and longing only to quit it. This has been observed in most of the oak plantations of which I have spoken, and they have not been able to attain to full growth. When the vegetation was perceived to languish, they were cut, in the hope that this operation would restore their vigor, and that the new shoots would succeed better than the original trees; and, in fact, they seemed to be recovering for the first few years. But the shoots were soon attacked by the same decay, and the operation had to be renewed at shorter and shorter intervals, until at last it was found necessary to treat as coppices plantations originally designed for the full-growth system. Nor was this all: the soil, periodically bared by these cuttings, became impoverished, and less and less suited to the growth of the oak. . . It was then proposed to introduce the pine and plant with it the vacancies and glades. . . By this means, the forest was saved from the ruin which threatened it, and now more than 10,000 acres of pines, from fifteen to thirty years old, are disseminated at various points, sometimes intermixed with broad-leaved trees, sometimes forming groves by themselves."—*Revue des Deux Mondes*, Mai, 1863, pp. 153, 154.

like most fish and reptiles, has no natural limit of life or of growth, and that the only reason why our oaks and our pines do not reach the age of twenty centuries and the height of a hundred fathoms, is, that in the multitude of accidents to which they are exposed, the chances of their attaining to such a length of years and to such dimensions of growth are millions to one against them. But another explanation of this fact is possible. In trees affected by no discoverable external cause of death, decay begins at the topmost branches, which seem to wither and die for want of nutriment. The mysterious force by which the sap is carried from the roots to the utmost twigs, cannot be conceived to be unlimited in power, and it is probable that it differs in different species, so that while it may suffice to raise the fluid to the height of five hundred feet in the eucalyptus, it may not be able to carry it beyond one hundred and fifty in the oak. The limit may be different, too, in different trees of the same species, not from defective organization in those of inferior growth, but from more or less favorable conditions of soil, nourishment, and exposure. Whenever a tree attains to the limit beyond which its circulating fluids cannot rise, we may suppose that decay begins, and death follows from want of nutrition at the extremities, and from the same causes which bring about the same results in animals of limited size—such, for example, as the interruption of functions essential to life, in consequence of the clogging up of ducts by matter assimilable in the stage of growth, but no longer so when increment has ceased.

In the natural woods we observe that, though, among the myriads of trees which grow upon a square mile, there are several vegetable giants, yet the great majority of them begin to decay long before they have attained their maximum of stature, and this seems to be still more emphatically true of the artificial forest. In France, according to Clavé, "oaks, in a suitable soil, may stand, without exhibiting any sign of decay, for two or three hundred years; the pines hardly exceed one hundred and twenty, and the soft or white woods [*bois blancs*], in wet soils, languish and die before reaching the fiftieth year." * These ages are certainly below the average of those of American forest-trees, and are greatly exceeded in very numerous well-attested instances of isolated trees in Europe.

The former mode of treating the futaie, called the garden system, was to cut the trees individually as they arrived at maturity, but, in the best regulated forests, this practice has been abandoned for the German method, which embraces not only the securing of the largest immediate profit, but the re-planting of the forest, and the care of the young growth. This is effected in the case of a forest, whether natural or artificial, which is to be subjected to regular management, by three operations. The first of these consists in felling about one-third of the trees, in such way as to leave convenient spaces for the growth of seedlings. The remaining two-thirds are relied upon to replant the vacancies, by natural sowing, which they seldom or never fail to do. The seedlings are watched, are thinned out when too dense, and the ill-formed and sickly, as well as those of species of inferior value, and the shrubs and thorns which might otherwise choke or too closely shade them, are pulled up. When they have attained sufficient strength and development of foliage to require, or at least to bear, more light and air, the second step is taken, by removing a suitable proportion of the old trees which had been spared at the first cutting; and when, finally, the younger trees are hardened enough to bear frost and sun without other protection than that which they mutually give to each other, the remainder of the original forest is felled, and the wood now consists wholly of young and vigorous trees. This result is obtained after about twenty years. At convenient periods, the unhealthy stocks and those injured by wind or other accidents are removed, and in some instances the growth of the remainder is promoted by irrigation or by fertilizing applications.† When the forest is approaching

---

* *Études Forestières*, p. 89.

† The grounds which it is most important to clothe with wood as a conservative influence, and which, also, can best be spared from agricultural use,

to maturity, the original processes already described are repeated; and as, in different parts of an extensive forest, they would take place at different times in different zones, it would afford indefinitely an annual crop of small wood, fuel, and timber.

The duties of the forester do not end here, for it sometimes happens that the glades left by felling the older trees are not sufficiently seeded, or that the species, or *essences*, as the French oddly call them, are not duly proportioned in the new crop. In this case, seed must be artificially sown, or young trees planted in the vacancies. Besides this, all trees, whether grown for fruit, for fuel, or for timber, require more or less training in

---

are steep hillsides. But the performance of all the offices of the forester to the tree—seeding, planting, thinning, trimming, and finally felling and removing for consumption—is more laborious upon a rapid declivity than on a level soil, and at the same time it is difficult to apply irrigation or manures to trees so situated. Experience has shown that there is great advantage in terracing the face of a hill before planting it, both as preventing the wash of the earth by checking the flow of water down its slope, and as presenting a surface favorable for irrigation, as well as for manuring and cultivating the tree. But even without so expensive a process, very important results have been obtained by simply ditching declivities. "In order to hasten the growth of wood on the flanks of a mountain, Mr. Eugène Chevandier divided the slope into zones forty or fifty feet wide, by horizontal ditches closed at both ends, and thereby obtained, from firs of different ages, shoots double the dimensions of those which grew on a dry soil of the same character, where the water was allowed to run off without obstruction."—DUMONT, *Des Travaux Publics*, etc., pp. 94–96.

The ditches were about two feet and a half deep, and three feet and a half wide, and they cost about forty francs the hectare, or three dollars the acre. This extraordinary growth was produced wholly by the retention of the rain-water in the ditches, whence it filtered through the whole soil and supplied moisture to the roots of the trees. It may be doubted whether in a climate cold enough to freeze the entire contents of the ditches in winter, it would not be expedient to draw off the water in the autumn, as the presence of so large a quantity of ice in the soil might prove injurious to trees too young and small to shelter the ground effectually against frost.

Chevandier computes that, if the annual growth of the pine in the marshy and too humid soil of the Vosges be represented by one, it will equal two in ordinary dry ground, four or five on slopes so ditched or graded as to retain the water flowing upon them from roads or steep declivities, and six where order to yield the best returns. The experiments of the Vicomte de Courval in sylviculture throw much light on this subject, and show, in a most interesting way, the importance of pruning forest-trees. The principal feature of De Courval's very successful method is a systematical mode of trimming which compels the tree to develop the stem, by reducing the lateral ramification. Beginning with young trees, the buds are rubbed off from the stems, and superfluous lateral shoots are pruned down to the trunk. When large trees are taken in hand, branches which can be spared, and whose removal is necessary to obtain a proper length of stem, are very smoothly cut off quite close

---

the earth is kept sufficiently moist by infiltration from running brooks.—*Comptes Rendus à l'Académie des Sciences*, t. xix., Juillet, Déc., 1844, p. 167.

The effect of accidental irrigation is well shown in the growth of the trees planted along the canals of irrigation which traverse the fields in many parts of Italy. They flourish most luxuriantly, in spite of continual lopping, and yield a very important contribution to the stock of fuel for domestic use; while trees, situated so far from canals as to be out of the reach of infiltration from them, are of much slower growth, under circumstances otherwise equally favorable.

In other experiments of Chevandier, under better conditions, the yield of wood was increased, by judicious irrigation, in the ratio of seven to one, the profits in that of twelve to one. At the Exposition of 1855, Chambrelent exhibited young trees, which, in four years from the seed, had grown to the height of sixteen and twenty feet, and the circumference of ten and twelve inches. Chevandier experimented with various manures, and found that some of them might be profitably applied to young but not to old trees, the quantity required in the latter case being too great. Wood-ashes and the refuse of soda factories are particularly recommended. See, on the manuring of trees, CHEVANDIER, *Recherches sur l'emploi de divers amendements*, etc., Paris, 1852, and KODERLE, *Grundsätze der Künstlichen Düngung im Forstculturwesen*. Wien, 1865.

I have seen an extraordinary growth produced in fir-trees by the application of soapsuds; in a young and sickly cherry-tree, by heaping the chips and dust from a marble-quarry, to the height of two or three feet, over the roots and around the stem; and cases have come to my knowledge where like results followed the planting of vines and trees in holes half filled with fragments of plaster-castings, and mortar from old buildings. Chevandier's experiments in the irrigation of the forest would not have been a "new thing under the sun" to wise King Solomon, for that monarch says: "I made me pools of water, to water therewith the wood that bringeth forth trees." Eccles. ii. 6.

to the trunk, and the exposed surface is *immediately* brushed over with mineral-coal tar. When thus treated, it is said that the healing of the wound is perfect, and without any decay of the tree. Trees trained by De Courval's method, which is now universally approved and much practised in France, rapidly attain a great height. They grow with remarkable straightness of stem and of grain, and their timber commands the highest price.[*]

A system of plantation, specially though not exclusively suited to very moist soils, recommended by Duhamel a hundred years ago, has been revived in Germany, within about twenty years, with much success. It is called *hill-planting*, and consists in placing the young tree upright on the greensward with its roots properly spread out, and then covering the roots and supporting the trunk by thick sods cut so as to form a circular hillock around it.[†] By this method it is alleged trees can be grown advantageously both in dry ground and on humid soils, where they would not strike root if planted in holes after the usual manner. If there is any truth in the theory of a desiccating action in evergreen trees, plantations of this sort might have a value as drainers of lands not easily laid dry by other processes. There is much ground on the great prairies of the West, where experiments with this method of planting are strongly to be recommended.

It is common in Europe to permit the removal of the fallen leaves and fragments of bark and branches with which the forest-soil is covered, and sometimes the cutting of the lower twigs of evergreens. The leaves and twigs are principally used as litter for cattle, and finally as manure, the bark and wind-fallen branches as fuel. By long usage, sometimes by express grant, this privilege has become a vested right of the population in the neighborhood of many public and even large private forests; but it is generally regarded as a serious evil. To remove the leaves and fallen twigs is to withdraw much of the pabulum upon which the tree was destined to feed. The small branches and leaves are the parts of the tree which yield the largest proportion of ashes on combustion, and of course they supply a great amount of nutriment for the young shoots. "A cubic foot of twigs," says Vaupell, "yields four times as much ashes as a cubic foot of stem wood. . . For every hundred weight of dried leaves carried off from a beech forest, we sacrifice a hundred and sixty cubic feet of wood. The leaves and the mosses are a substitute, not only for manure, but for ploughing. The carbonic acid given out by decaying leaves, when taken up by water, serves to dissolve the mineral constituents of the soil, and is particularly active in disintegrating feldspar and the clay derived from its decomposition. . . . The leaves belong to the soil. Without them it cannot preserve its fertility, and cannot furnish nutriment to the beech. The trees languish, produce seed incapable of germination, and the spontaneous self-sowing, which is an indispensable element in the best systems of sylviculture, fails altogether in the bared and impoverished soil." *

---

[*] See DE COURVAL, *Taille et conduite des Arbres forestières et autres arbres de grande dimension.* Paris, 1861.

The most important part of Viscount de Courval's system will be found in *L'Élagage des Arbres, par le Comte A. Des Cars*, an admirable little treatise, of which numerous editions, at the price of one franc, have been printed since the first, of 1864, and which ought to be translated and published without delay in the United States.

[†] See MANTEUFFEL, *L'Art de Planter, traduit par Stumper.* Paris, 1868.

Besides these evils, the removal of the leaves deprives the soil of much of that spongy character which gives it such im-

---

* VAUPELL, *Bögens Indvandring i de Danske Skove*, pp. 29, 46. Vaupell further observes, on the page last quoted: "The removal of leaves is injurious to the forest, not only because it retards the growth of trees, but still more because it disqualifies the soil for the production of particular species. When the beech languishes, and the development of its branches is less vigorous and its crown less spreading, it becomes unable to resist the encroachments of the fir. This latter tree thrives in an inferior soil, and being no longer stifled by the thick foliage of the beech, it spreads gradually through the wood, while the beech retreats before it and finally perishes."

Schleiden confirms the opinion of Vaupell, and adds many important observations on this subject.—*Für Baum und Wald*, pp. 64, 65.

mense value as a reservoir of moisture and a regulator of the flow of springs; and, finally, it exposes the surface-roots to the drying influence of sun and wind, to accidental mechanical injury from the tread of animals or men, and, in cold climates, to the destructive effects of frost.

Protection against Wild Animals.

It is often necessary to take measures for the protection of young trees against the rabbit, the mole, and other rodent quadrupeds, and of older ones against the damage done by the larvæ of insects hatched upon the surface or in the tissues of the bark, or even in the wood itself. The much greater liability of the artificial than of the natural forest to injury from this cause is perhaps the only point in which the superiority of the former to the latter is not as marked as that of any domesticated vegetable to its wild representative. But the better quality of the wood and the much more rapid growth of the trained and regulated forest are abundant compensations for the loss thus occasioned, and the progress of entomological science will, perhaps, suggest new methods of preventing the ravages of insects. Thus far, however, the collection and destruction of the eggs, by simple but expensive means, has proved the most effectual remedy.*

---

* I have remarked elsewhere that most insects which deposit and hatch their eggs in the wood of the natural forest confine themselves to dead trees. Not only is this the fact, but it is also true that many of the borers attack only freshly-cut timber. Their season of labor is a short one, and unless the tree is cut during this period, it is safe from them. In summer you may hear them plying their augers in the wood of a young pine with soft, green bark, as you sit upon its trunk, within a week after it has been felled, but the windfalls of the winter lie uninjured by the worm and even undecayed for centuries. In the pine woods of New England, after the regular lumberman has removed the standing trees, these old trunks are hauled out from the mosses and leaves which half cover them, and often furnish excellent timber. The slow decay of such timber in the woods, it may be remarked, furnishes another proof of the uniformity of temperature and humidity in the forest, for the trunk of a tree lying on grass or ploughland, and of course exposed to all the alterna-

Exclusion of Domestic Quadrupeds.

But probably the most important of all rules for the government of the forest, whether natural or artificial, is that which prescribes the absolute exclusion of all domestic quadrupeds, except swine, from every wood which is not destined to be cleared. No growth of young trees is possible where horned cattle, sheep, or goats, or even horses, are permitted to pasture at any season of the year, though they are doubtless most destructive when trees are in leaf.* These animals browse upon

---

tions of climate, hardly resists complete decomposition for a generation. The forests of Europe exhibit similar facts. Wessely, in a description of the primitive wood of Neuwald in Lower Austria, says that the windfalls required from 150 to 200 years for entire decay.—*Die Oesterreichischen Alpenländer und ihre Forste*, p. 312.

The comparative immunity of the American native forests from attacks by insects is perhaps in some degree due to the fact that the European destructive tribes have not yet found their way across the ocean, and that our native species are less injurious to living trees. On the European lignivorous insects, see Siemoni, *Manuale d'Arte Forestale*, 2d edizione, pp. 369–379.

* Although the economy of the forest has received little attention in the United States, no lover of American nature can have failed to observe a marked difference between a native wood from which cattle are excluded and one where they are permitted to browse. A few seasons suffice for the total extirpation of the "underbrush," including the young trees on which alone the reproduction of the forest depends, and all the branches of those of larger growth which hang within reach of the cattle are stripped of their buds and leaves, and soon wither and fall off. These effects are observable at a great distance, and a wood-pasture is recognized, almost as far as it can be seen, by the regularity with which its lower foliage terminates at what Ruskin somewhere calls the "cattle-line." This always runs parallel to the surface of the ground, and is determined by the height to which domestic quadrupeds can reach to feed upon the leaves. In describing a visit to the grand-ducal farm of San Rossore near Pisa, where a large herd of camels is kept, Chateauvieux says: "In passing through a wood of evergreen oaks, I observed that all the twigs and foliage of the trees were clipped up to the height of about twelve feet above the ground, without leaving a single spray below that level. I was informed that the browsing of the camels had trimmed the trees as high as they could reach."—Lullin de Chateauvieux, *Lettres sur l'Italie*, p. 113.

Browsing animals, and most of all the goat, are considered by foresters the terminal buds and the tender branches, thereby stunting, if they do not kill, the young trees, and depriving them of all beauty and vigor of growth.

---

as more injurious to the growth of young trees, and, therefore, to the reproduction of the forest, than almost any other destructive cause. According to Beatson's *Saint Helena*, introductory chapter, and Darwin's *Journal of Researches in Geology and Natural History*, pp. 582, 583, it was the goats which destroyed the beautiful forests that, three hundred and fifty years ago, covered a continuous surface of not less than two thousand acres in the interior of the island [of St. Helena], not to mention scattered groups of trees. Darwin observes: "During our stay at Valparaiso, I was most positively assured that sandal-wood formerly grew in abundance on the island of Juan Fernandez, but that this tree had now become entirely extinct there, having been extirpated by the goats which early navigators had introduced. The neighboring islands, to which goats have not been carried, still abound in sandal-wood."

In the winter, the deer tribe, especially the great American moose-deer, subsists much on the buds and young sprouts of trees; yet—though from the destruction of the wolves or from some not easily explained cause, these latter animals have recently multiplied so rapidly in some parts of North America, that, not long since, four hundred of them are said to have been killed, in one season, on a territory in Maine not comprising more than one hundred and fifty square miles—the wild browsing quadrupeds are rarely, if ever, numerous enough in regions uninhabited by man to produce any sensible effect on the condition of the forest. A reason why they are less injurious than the goat to young trees may be that they resort to this nutriment only in the winter, when the grasses and shrubs are leafless or covered with snow, whereas the goat feeds upon buds and young shoots principally in the season of growth. However this may be, the natural law of consumption and supply keeps the forest growth, and the wild animals which live on its products, in such a state of equilibrium as to insure the indefinite continuance of both, and the perpetuity of neither is endangered until man interferes and destroys the balance.

When, however, deer are bred and protected in parks, they multiply like domestic cattle, and become equally injurious to trees. "A few years ago," says Clavé, "there were not less than two thousand deer of different ages in the forest of Fontainebleau. For want of grass, they are driven to the trees, and they do not spare them. . . It is calculated that the browsing of these animals, and the consequent retardation of the growth of the wood, diminishes the annual product of the forest to the amount of two hundred thousand cubic feet per year, . . and besides this, the trees thus mutilated are soon exhausted and die. The deer attack the pines, too, tearing off the bark in long strips, or rubbing their heads against them when shedding their

Forest Fires.

The difficulty of protecting the woods against accidental or incendiary fires is one of the most discouraging circumstances attending the preservation of natural and the plantation of artificial forests.* In the spontaneous wood the spread of fire is

---

horns; and sometimes, in groves of more than a hundred hectares, not one pine is found uninjured by them."—*Revue des Deux Mondes*, Mai, 1863, p. 157.

Vaupell, though agreeing with other writers as to the injury done to the forest by most domestic animals and by half-tamed deer—which he illustrates in an interesting way in his posthumous work, *The Danish Woods*—thinks, nevertheless, that at the season when the mast is falling, swine are rather useful than otherwise to forests of beech and oak, by treading into the ground and thus sowing beechnuts and acorns, and by destroying moles and mice.—*De Danske Skove*, p. 12. Meguscher is of the same opinion, and adds that swine destroy injurious insects and their larvæ.—*Memoria*, etc., p. 233.

Beckstein computes that a park of 2,500 acres, containing 250 acres of marsh, 250 of fields and meadows, and the remaining 2,000 of wood, may keep 364 deer of different species, 47 wild boars, 200 hares, 100 rabbits, and an indefinite number of pheasants. These animals would require, in winter, 123,000 pounds of hay, and 22,000 pounds of potatoes, besides what they would pick up themselves. The natural forest most thickly peopled with wild animals would not, in temperate climates, contain, upon the average, one-tenth of these numbers to the same extent of surface.

* The disappearance of the forests of ancient Gaul and of mediæval France has been ascribed by some writers as much to accidental fires as to the felling of the trees. All the treatises on sylviculture are full of narratives of forest fires. The woods of Corsica and Sardinia have suffered incalculable injury from this cause, and notwithstanding the resistance of the cork-tree to injury from common fires, the government forests of this valuable tree in Algeria have been lately often set on fire by the natives and have sustained immense damage.

See an article by Ysabeau in the *Annales Forestières*, t. iii., p. 439; DELLA MARMORA, *Voyage en Sardaigne*, 2d edition, t. i., p. 426; *Rivista Forestale del Regno d'Italia*, October, 1865, p. 474.

Five or six years ago I saw in Switzerland a considerable forest, chiefly of young trees, which had recently been burnt over. I was told that the poor of the commune had long enjoyed a customary privilege of carrying off dead wood and windfalls, and that they had set the forest on fire to kill the trees and so increase the supply of their lawful plunder.

The customary rights of herdsmen, shepherds, and peasants in European somewhat retarded by the general humidity of the soil and of the beds of leaves which cover it. But in long droughts the superficial layer of leaves and the dry fallen branches become as inflammable as tinder, and the fire spreads with fearful rapidity, until its further progress is arrested by want of material, or, more rarely, by heavy rains, sometimes caused, as many meteorologists suppose, by the conflagration itself.

In the artificial forest the annual removal of fallen or half-dried trees and the leaves and other droppings of the wood, though otherwise a very injurious practice, much diminishes the rapid spread of fires; and the absence of combustible underwood and the greater distance between the trees are additional safeguards. But, on the other hand, the comparative dryness of the soil, and of any leaves or twigs which may remain upon it, and the greater facility for the passage of wind-currents through a regularly planted and more open wood, are circumstances unfavorable to the security of the trees against this formidable danger. The natural forest, unless isolated and of small extent, can be protected from fire only by a vigilance too costly to be systematically practised. But the artificial wood may be secured by a network of ditches and of paths or occasional open glades, which both check the running of the fire and furnish the means of approaching and combating it.*

The experience of 1871 ought not to be wholly without value as a lesson. It is not possible to estimate the damage by forest fires in that disastrous year, in what were lately the North-western States, and in Canada, but as the demand for lumber, and, consequently, its market price, are rising at a rate higher than the interest on capital, in a geometrical ratio, one may almost

---

forests are often an insuperable obstacle to the success of attempts to preserve the woods or to improve their condition. See, on this subject, ALFRED MAURY, *Les anciens Forêts de la Gaule*, chap. xxix.

* It is stated that in the pine woods of the Landes of Gascony a fire has never been known to cross a railway-track or a common road. See *Des Incendies, etc., dans la Region des Maures* in the *Revue des Eaux et Forêts* for February, 1869. Many other important articles on this subject will be found in other numbers of the same very valuable periodical.

say it is probable that ten years hence those fires will be thought to have diminished the national wealth by a larger amount than even the terrible conflagration at Chicago.

There is no good reason why insurance companies should not guarantee the proprietor of a wood as well as the owner of a house against damage by fire. In Europe there is no conceivable liability to pecuniary loss which may not be insured against. The American companies might at first be embarrassed in estimating the risk, but the experience of a few years would suggest safe principles, and all parties would find advantage in this extension of security.

Forest Legislation.

I have alleged sufficient reasons for believing that a desolation, like that which has overwhelmed many once beautiful and fertile regions of Europe, awaits an important part of the territory of the United States, and of other comparatively new countries over which European civilization is now extending its sway, unless prompt measures are taken to check the action of destructive causes already in operation. It is almost in vain to expect that mere restrictive legislation can do anything effectual to arrest the progress of the evil in those countries, except so far as the state is still the proprietor of extensive forests. Woodlands which have passed into private hands will everywhere be managed, in spite of legal restrictions, upon the same economical principles as other possessions, and every proprietor will, as a general rule, fell his woods, unless he believes that it will be for his pecuniary interest to preserve them. Few of the new provinces which the last three centuries have brought under the control of the European race, would tolerate any interference by the law-making power with what they regard as the most sacred of civil rights—the right, namely, of every man to do what he will with his own. In the Old World, even in France, whose people, of all European nations, love best to be governed and are least annoyed by bureaucratic supervision, law has been found impotent to prevent the destruction, or wasteful economy, of private forests; and in many of the mountainous departments of that country, man is at this moment so fast laying waste the face of the earth, that the most serious fears are entertained, not only of the depopulation of those districts, but of enormous mischiefs to the provinces contiguous to them.[*] The only legal provisions from which anything is to be hoped, are such as shall make it a matter of private advantage to the landholder to spare the trees upon his grounds, and promote the growth of the young wood. Much may be done by exempting standing forests from taxation, and by imposing taxes on wood felled for fuel or for timber, something by more stringent provisions against trespasses on forest property, and something by premiums or honorary distinctions for judicious management of the woods; and, in short, in this matter rewards rather than punishments must be the incentives to obedience even to a policy of enlightened self-interest. It might be difficult to induce governments, general or local, to make the necessary appropriations for such purposes, but there can be no doubt that it would be sound economy in the end.

---

[*] "The laws against clearing have never been able to prevent these operations when the proprietor found his advantage in them, and the long series of royal ordinances and decrees of parliaments, proclaimed from the days of Charlemagne to our own, with a view of securing forest property against the improvidence of its owners, have served only to show the impotence of legislative action on this subject."—CLAVÉ, *Études sur l'Économie Forestière*, p. 32.

"A proprietor can always contrive to clear his woods, whatever may be done to prevent him; it is a mere question of time, and a few imprudent cuttings, a few abuses of the right of pasturage, suffice to destroy a forest in spite of all regulations to the contrary."—DUNOYER, *De la Liberté du Travail*, ii., p. 452, as quoted by Clavé, p. 353.

Both authors agree that the preservation of the forests in France is practicable only by their transfer to the state, which alone can protect them and secure their proper treatment. It is much to be feared that even this measure would be inadequate to preserve the forests of the American Union. There is little respect for public property in America, and the Federal Government, certainly, would not be the proper agent of the nation for this purpose. It proved itself unable to protect the live-oak woods of Florida, which were intended to be preserved for the use of the navy, and it more than once paid contractors a high price for timber stolen from its own forests. The authorities of the individual States might be more efficient.

In countries where there exist municipalities endowed with an intelligent public spirit, the purchase and control of forests by such corporations would often prove advantageous; and in some of the provinces of Northern Lombardy, experience has shown that such operations may be conducted with great benefit to all the interests connected with the proper management of the woods. In Switzerland, on the other hand, except in some few cases where woods have been preserved as a defence against avalanches, the forests of the communes have been of little advantage to the public interests, and have very generally gone to decay.* The rights of pasturage, everywhere destructive to trees, combined with toleration of trespasses, have so reduced their value, that there is, too often, nothing left that is worth protecting. In the canton of Ticino, the peasants have very frequently voted to sell the town-woods and divide the proceeds among the corporators. The sometimes considerable sums thus received are squandered in wild revelry, and the sacrifice of the forests brings not even a momentary benefit to the proprietors.†

Fortunately for the immense economical and sanitary interests involved in this branch of rural and industrial husbandry, public opinion in many parts of the United States is thoroughly roused to the importance of the subject. In the Eastern States, plantations of a certain extent have been made, and a wiser system is pursued in the treatment of the remaining native woods.‡ Important experiments have been tried in

---

* A better economy has been of late introduced into the management of the forest in Switzerland. Excellent official reports on the subject have been published and important legal provisions adopted.

† See in BERLEPSCH, *Die Alpen*, chapter *Holzschläger und Flösser*, a lively account of the sale of a communal wood.

‡ When the census of 1860 was taken, the States of Maine and New York produced and exported lumber in abundance. Neither of them now has timber enough for domestic use, and they are both compelled to draw much of their supply from Canada and the West.

Massachusetts on the propagation of forest-trees on seashore bluffs exposed to strong winds. This had been generally supposed to be impossible, but the experiments in question afford a gratifying proof that this is an erroneous opinion. Piper gives an interesting account of Mr. Tudor's success in planting trees on the bleak and barren shore of Nahant. "Mr. Tudor," observes he, "has planted more than ten thousand trees at Nahant, and, by the results of his experiments, has fully demonstrated that trees, properly cared for in the beginning, may be made to grow up to the very bounds of the ocean, exposed to the biting of the wind and the spray of the sea. The only shelter they require is, at first, some interruption to break the current of the wind, such as fences, houses, or other trees." *

Young trees protected against the wind by a fence will somewhat overtop their shelter, and every tree will serve as a screen to a taller one behind it. Extensive groves have thus been formed in situations where an isolated tree would not grow at all.

The people of the Far West have thrown themselves into the work, we cannot say of restoration, but rather of creation, of woodland, with much of the passionate energy which marks their action in reference to other modes of physical improvement. California has appointed a State forester with a liberal salary, and made such legal provisions and appropriations as to render the discharge of his duties effectual. The hands that built the Pacific Railroad at the rate of miles in a day are now busy in planting belts of trees to shelter the track from snowdrifts, and to supply, at a future day, timber for ties and fuel for the locomotives. The settlers on the open plains, too, are not less actively engaged in the propagation of the woods, and if we can put faith in the official statistics on the subject, not thousands but millions of trees are annually planted on the prairies.

These experiments are of much scientific as well as economical interest. The prairies have never been wooded, so far as we know their history, and it has been contended that successful

---

* *Trees of America*, p. 10.

sylviculture would be impracticable in those regions from the want of rain. But we are acquainted with no soil and climate which favor the production of herbage and forbid the rearing of trees, and, as Bryant well observes, "it seems certain that where grass will grow trees may be made to grow also." * In

---

* The origin of our Western treeless prairies and plains, as of the Russian steppes, which much resemble them, is obscure, but the want of forests upon them, seems to be due to climatic conditions and especially to a want of spring and summer rains, which prevents the spontaneous formation of forests upon them, though not necessarily the growth of trees artificially planted and cared for. Climatic conditions more or less resembling those of our Western territories produce analogous effects in India. Much valuable information on the relations between climate and forest vegetation will be found in an article by Dr. BRANDIS, *On the Distribution of Forests in India*, in *Ocean Highways* for October, 1872.

In the more eastwardly prairie region fires have done much to prevent the spread of the native groves, and throughout the whole woodless plains the pasturage of the buffalo alone would suffice to prevent a forest growth. The prairies were the proper feeding-grounds of the bison, and the vast number of those animals is connected, as cause or consequence, with the existence of these vast pastures. The bison, indeed, could not convert the forest into a pasture, but he would do much to prevent the pasture from becoming a forest.

There is positive evidence that some of the American tribes possessed large herds of domesticated bisons. See HUMBOLDT, *Ansichten der Natur*, i., pp. 71–73. What authorizes us to affirm that this was simply the wild bison reclaimed, and why may we not, with equal probability, believe that the migratory prairie-buffalo is the progeny of the domestic animal run wild?

There are, both on the prairies, as in Wisconsin, and in deep forests, as in Ohio, extensive remains of a primitive people, who must have been more numerous and more advanced in art than the present Indian tribes. There can be no doubt that the woods where such earthworks are found in Ohio were cleared by them, and that the vicinity of these fortresses or temples was inhabited by a large population. Nothing forbids the supposition that the prairies were cleared by the same or a similar people, and that the growth of trees upon them has been prevented by fires and grazing, while the restoration of the woods in Ohio may be due to the abandonment of that region by its original inhabitants. The climatic conditions unfavorable to the spontaneous growth of trees on the prairies may possibly be an effect of too extensive clearings, rather than a cause of the want of woods.

It is disputed whether the steppes of Russia were ever wooded. They were certainly bare of forest growth at a very remote period; for Herodotus describes the country of the Scythians between the Ister and the Tanais as any case the question will now be subjected to a practical test, and the plantations are so extensive, and, as is reported, so thrifty in growth, that one generation will suffice to determine with certainty and precision how far climate is affected by clothing with wood a vast territory naturally destitute of that protection.

I have thus far spoken only of the preservation and training of existing woods, not of the planting of new forests, because European experience, to which alone we can appeal, is conversant only with conditions so different from those of our own climate, soil, and arboreal vegetation, that precedents drawn from it cannot be relied upon as entirely safe rules for our guidance in that branch of rural economy.*

---

woodless, with the exception of the small province of Xylæa between the Dnieper and the Gulf of Perekop. They are known to have been occupied by a large nomade and pastoral population down to the sixteenth century, though these tribes are now much reduced in numbers. The habits of such races are scarcely less destructive to the forest than those of civilized life. Pastoral tribes do not employ much wood for fuel or for construction, but they carelessly or recklessly burn down the forests, and their cattle effectually check the growth of young trees wherever their range extends.

At present, the furious winds which sweep over the plains, the droughts of summer, and the rights and abuses of pasturage, constitute very formidable obstacles to the employment of measures which have been attended with so valuable results on the sand-wastes of France and Germany. The Russian Government has, however, attempted the wooding of the steppes, and there are thriving plantations in the neighborhood of Odessa, where the soil is of a particularly loose and sandy character. The tree best suited to this locality, and, as there is good reason to suppose, to sand plains in general, is the *Ailanthus glandulosa*, or Japan varnish-tree. The remarkable success which has crowned the experiments with the ailanthus at Odessa, will, no doubt, stimulate to similar trials elsewhere, and it seems not improbable that the arundo and the maritime pine, which have fixed so many thousand acres of drifting sands in Western Europe, will be, partially at least, superseded by the tamarisk and the varnish-tree.

According to Hohenstein, *Der Wald*, pp. 228, 229, an extensive plantation of pines—a tree new to Southern Russia—was commenced in 1842, on the barren and sandy banks of the Ingula, near Elisabethgrod, and has met with very flattering success. Other experiments in sylviculture at different points on the steppes promise valuable results.

* Many valuable suggestions on this subject will be found in Bryant, *Forest Trees*, chap. vi. *et seqq.*

I apprehend that one rule, which is certainly alike applicable to both sides of the Atlantic—that, namely, of the absolute exclusion of domestic quadrupeds from all woods, old or young, not destined for the axe—would be least likely to be observed in our practice. The need of shade for cattle, and our inveterate habits in this respect, are much more serious obstacles to compliance with this precept than any inherent difficulty in the thing itself; for there is no good reason why our cattle may not be kept out of our woods as well as out of our wheatfields. When forest-planting is earnestly and perseveringly practised, means of overcoming this difficulty will be found, and our husbandry will be modified to meet the exigency.

The best general advice that can be offered, in the want of an experimental code, is to make every plantation consist of a great variety of trees, and this not only because nature favors a diversified forest-crop, but because the chances of success among a multitude of species are far greater than if we confine ourselves to one or two.

It will doubtless be found that in our scorching summer, especially on bare plains, shade for young plants is even more necessary than in most parts of Europe, and hence a fair proportion of rapidly growing trees and shrubs, even if themselves of little intrinsic value, ought to be regarded as an indispensable feature in every young plantation. These trees should be of species which bear a full supply of air and light, and therefore, in the order of nature, precede those which are of greater value for the permanent wood; and it would be a prudent measure to seed the ground with a stock of such plants, a year or two before sowing or transplanting the more valuable varieties.

More specific rules than these cannot at present well be given, but very brief experiments, even if not in all respects wisely conducted, will suffice to determine the main question: whether in a given locality this or that particular tree can advantageously be propagated or introduced. The special processes of arboriculture suited to the ends of the planter may be gathered partly from cautious imitation of European practice, and partly from an experience which, though not pronouncing definitively in a single season, will, nevertheless, suggest appropriate methods of planting and training the wood within a period not disproportioned to the importance of the object.*

The growth of arboreal vegetation is comparatively slow, and we are often told that, though he who buries an acorn may hope to see it shoot up to a miniature resemblance of the majestic tree which shall shade his remote descendants, yet the longest life hardly embraces the seedtime and the harvest of a forest. The planter of a wood, it is said, must be actuated by higher motives than those of an investment, the profits of which consist in direct pecuniary gain to himself or even to his posterity; for if, in rare cases, an artificial forest may, in a generation or two, more than repay its original cost, still, in general, the value of its timber will not return the capital expended and the interest accrued.†

---

* For very judicious suggestions on experiments in sylviculture, see the Rev. Frederick Starr's remarkable paper on the American Forests in the *Transactions of the Agricultural Society* for ——.

† According to Clavé (*Études*, p. 159), the net revenue from the forests of the state in France, making no allowance for interest on the capital represented by the forest, is two dollars per acre. In Saxony it is about the same, though the cost of administration is twice as much as in France; in Würtemberg it is about a dollar an acre; and in Prussia, where half the income is consumed in the expenses of administration, it sinks to less than half a dollar. This low rate in Prussia and other German states is partly explained by the fact that a considerable proportion of the annual product of the wood is either conceded to persons claiming prescriptive rights, or sold, at a very small price, to the poor. Taking into account the capital invested in forest-land, and adding interest upon it, Pressler calculates that a pine wood, managed with a view to felling it when eighty years old, would yield one-eighth of one per cent. annual profit; a fir wood, at one hundred years, one-sixth of one per cent.; a beech wood, at one hundred and twenty years, one-fourth of one per cent. The same author gives the net income of the New Forest in England, over and above expenses, interest not computed, at twenty-five cents per acre only. In America, where no expense is bestowed upon the woods, the value of the annual growth has generally been estimated much higher.

Forest-trees are often planted in Europe for what may be called an early crop. Thus in Germany acorns are sown and the young seedlings cultivated like ordinary field-vegetables, and cut at the age of a very few years for the

But the modern improved methods of sylviculture show vastly more favorable financial results; and when we consider the immense collateral advantages derived from the presence of the forest, the terrible evils necessarily resulting from its destruction, we cannot but admit that the preservation of existing woods, and the more costly extension and creation of them where they have been unduly reduced or have never existed, are among the plainest dictates of self-interest and most obvious of the duties which this age owes to those that are to come after it.

Financial Results of Forest Plantation.

Upon the whole, I am persuaded that the financial statistics which are found in French and German authors, as the results of European experience in forest economy, present the question under a too unfavorable aspect; and therefore these calculations ought not to discourage landed proprietors from making experiments on this subject. These statistics apply to woods whose present condition is, in an eminent degree, the effect of previous long-continued mismanagement; and there is much reason to believe that in the propitious climate of the United States new plantations, regulated substantially according to the methods of De Courval, Chambrelent, and Chevandier, and accompanied with the introduction of exotic trees, as, for example, the Australian caruarina and eucalyptus*—which latter, it is

---

sake of the bark and the young twigs used by tanners. In England, trees are grown at the rate of two thousand to the acre, and cut for props in the mines at the diameter of a few inches. Plantations for hoop-poles, and other special purposes requiring small timber, would, no doubt, often prove highly remunerative.

* Although the eucalyptus thrives admirably in Algeria—where it attains a height of from fifty to sixty feet, and a diameter of fifteen or sixteen inches, in six years from the seed—and in some restricted localities in Southern Europe, it will not bear the winters even of Florence, and consequently cannot be expected to flourish in any part of the United States except the extreme South and California. The writer of a somewhat enthusiastic article on this latter State, in Harper's Monthly for July, 1872, affirms that he saw a

said, has a growth at least five, and, according to some, ten times more rapid than that of the oak—would prove good investments even in an economical aspect.*

There is no doubt that they would pay the expenses of their planting at no distant period, at least in every case where irrigation is possible, and in very many situations, terraces, ditches, or even horizontal furrows upon the hillsides, would answer as a substitute for more artificial irrigation. Large proprietors would receive important indirect benefits from the shelter and the moisture which forests furnish for the lands in their neighborhood, and eventually from the accumulation of vegetable mould in the woods.† The security of the investment, as in the case of all real-estate, is a strong argument for undertaking such plantations, and a moderate amount of government patron-

---

eucalyptus "eight years from a small cutting, which was seventy-five feet in height, and two feet and a half in diameter at the base."

The paulownia, which thrives in Northern Italy, has a wood of little value, but the tree would serve well as a shelter for seedlings and young plants of more valuable species, and in other cases where a temporary shade is urgently needed. The young shoots, from a stem polled the previous season, almost surpass even the eucalyptus in rapidity of growth. Such a shoot from a tree not six inches in diameter, which I had an opportunity of daily observing, from the bursting out of the bud from the bark of the parent stem in April till November of the same year, acquired in that interval a diameter of between four and five inches and a height of above twenty feet.

* The economical statistics of GRIGOR, *Arboriculture*, Edinburgh, 1868, are very encouraging. In the preface to that work the author says: "Having formed several large plantations nearly forty years ago, which are still standing, in the Highlands of Scotland, I can refer to them as, after paying every expense, yielding a revenue equal to that of the finest arable land in the country, where the ground previously to these formations was not worth a shilling an acre." See also HARTIG, *Ueber den Wachsthumsgang und Ertrag der Buche, Eiche und Kiefer*, 1869, and especially BRYANT, *Forest Trees*, chap. ix.

† The fertility of newly cleared land is by no means due entirely to the accumulation of decayed vegetable matter on its surface, and to the decomposition of the mineral constituents of the soil by the gases emitted by the fallen leaves. Sachs has shown that the roots of living plants exercise a most powerful solvent action on rocks, and hence stones are disintegrated and resolved into elements of vegetable nutrition, by the chemical agency of the forest, more rapidly than by frost, rain, and other meteorological influences.

age and encouragement would be sufficient to render the creation of new forests an object of private interest as well as of public advantage, especially in a country where the necessity is so urgent and the climate so favorable as in the United States.

Instability of American Life.

All human institutions, associate arrangements, modes of life, have their characteristic imperfections. The natural, perhaps the necessary defect of ours, is their instability, their want of fixedness, not in form only, but even in spirit. The face of physical nature in the United States shares this incessant fluctuation, and the landscape is as variable as the habits of the population. It is time for some abatement in the restless love of change which characterizes us, and makes us almost a nomade rather than a sedentary people.* We have now felled forest enough everywhere, in many districts far too much. Let us restore this one element of material life to its normal proportions, and devise means of maintaining the permanence of its relations to the fields, the meadows, and the pastures, to the rain and the dews of heaven, to the springs and rivulets with which it waters the earth. The establishment of an approximately fixed ratio between the two most broadly characterized distinctions of rural surface—woodland and ploughland—would involve a certain persistence of character in all the branches of industry, all the occupations and habits of life, which depend upon or are immediately connected with either, without implying a rigidity that should exclude flexibility of accommodation to the many changes of external circumstance which human wisdom can neither prevent nor foresee, and would thus help us to become, more emphatically, a well-ordered and stable commonwealth, and, not less conspicuously, a people of progress.

---

* It is rare that a middle-aged American dies in the house where he was born, or an old man even in that which he has built; and this is scarcely less true of the rural districts, where every man owns his habitation, than of the city, where the majority live in hired houses. This life of incessant flitting is unfavorable for the execution of permanent improvements of every sort, and especially of those which, like the forest, are slow in repaying any part of the capital expended in them. It requires a very generous spirit in a landholder to plant a wood on a farm he expects to sell, or which he knows will pass out of the hands of his descendants at his death. But the very fact of having begun a plantation would attach the proprietor more strongly to the soil for which he had made such a sacrifice; and the paternal acres would have a greater value in the eyes of a succeeding generation, if thus improved and beautified by the labors of those from whom they were inherited. Landed property, therefore, the transfer of which is happily free from every legal impediment or restriction in the United States, would find, in the feelings thus prompted, a moral check against a too frequent change of owners, and would tend to remain long enough in one proprietor or one family to admit of gradual improvements which would increase its value both to the possessor and to the state.

CHAPTER IV.

THE WATERS.

Land Artificially won from the Waters—Great Works of Material Improvement—Draining of Lincolnshire Fens—Incursions of the Sea in the Netherlands—Origin of Sea-dikes—Gain and Loss of Land in the Netherlands—Marine Deposits on the Coast of Netherlands—Draining of Lake of Haarlem—Draining of the Zuiderzee—Geographical Effects of Improvements in the Netherlands—Ancient Hydraulic Works—Draining of Lake Celano by Prince Torlonia—Incidental Consequences of draining Lakes—Draining of Marshes—Agricultural Draining—Meteorological Effects of Draining—Geographical Effects of Draining—Geographical Effects of Aqueducts and Canals—Antiquity of Irrigation—Irrigation in Palestine, India, and Egypt—Irrigation in Europe—Meteorological Effects of Irrigation—Water withdrawn from Rivers for Irrigation—Injurious Effects of Rice-culture—Salts Deposited by Water of Irrigation—Subterranean Waters—Artesian Wells—Artificial Springs—Economizing Precipitation—Inundations in France—Basins of Reception—Diversion of Rivers—Glacier Lakes—River Embankments—Other Remedies against Inundations—Dikes of the Nile—Deposits of Tuscan Rivers—Improvements in Tuscan Maremma—Improvements in Val di Chiana—Coast of the Netherlands.

Land artificially won from the Waters.

MAN, as we have seen, has done much to revolutionize the solid surface of the globe, and to change the distribution and proportions, if not the essential character, of the organisms which inhabit the land and even the waters. Besides the influence thus exerted upon the life which peoples the sea, his action upon the land has involved a certain amount of indirect encroachment upon the territorial jurisdiction of the ocean. So far as he has increased the erosion of running waters by the destruction of the forest or by other operations which lessen the cohesion of the soil, he has promoted the deposit of solid matter in the sea, thus reducing the depth of marine estuaries, advancing the coast-line, and diminishing the area covered by the waters. He has gone beyond this, and invaded the realm of the ocean by constructing within its borders wharves, piers, light-houses, breakwaters, fortresses, and other facilities for his commercial and military operations; and in some countries he has permanently rescued from tidal overflow, and even from the very bed of the deep, tracts of ground extensive enough to constitute valuable additions to his agricultural domain. The quantity of soil gained from the sea by these different modes of acquisition is, indeed, too inconsiderable to form an appreciable element in the comparison of the general proportion between the two great forms of terrestrial surface, land and water; but the results of such operations, considered in their physical and their moral bearings, are sufficiently important to entitle them to special notice in every comprehensive view of the relations between man and nature.

There are cases, as on the western shores of the Baltic, where, in consequence of the secular elevation of the coast, the sea appears to be retiring; others, where, from the slow sinking of the land, it seems to be advancing. These movements depend upon geological causes wholly out of our reach, and man can neither advance nor retard them.*

---

* It is possible that the weight of the sediment let fall at the mouths of great rivers, like the Ganges, the Mississippi, and the Po, may cause the depression of the strata on which they are deposited, and hence if man promotes the erosion and transport of earthy material by rivers, he augments the weight of the sediment they convey into their estuaries, and consequently his action tends to accelerate such depression. There are, however, cases where, in spite of great deposits of sediment by rivers, the coast is rising. Further, the manifestation of the internal heat of the earth at any given point is conditioned by the thickness of the crust at such point. The deposits of rivers tend to augment that thickness at their estuaries. The sediment of slowly-flowing rivers emptying into shallow seas is spread over so great a surface that we can hardly imagine the foot or two of slime they let fall over a wide area in a century to form an element among even the infinitesimal quantities which compose the terms of the equations of nature. But some swift rivers, rolling mountains of fine earth, discharge themselves into deeply scooped gulfs or bays, and in such cases the deposit amounts, in the course of a few years, to a mass the transfer of which from the surface of a large basin,

There are also cases where similar apparent effects are produced by local oceanic currents, by river deposit or erosion, by tidal action, or by the influence of the wind upon the waves and the sands of the seabeach. A regular current may drift suspended earth and seaweed along a coast until they are caught by an eddy and finally deposited out of the reach of further disturbance, or it may scoop out the bed of the sea and undermine promontories and headlands; a powerful river, as the wind changes the direction of its flow at its outlet, may wash away shores and sandbanks at one point to deposit their material at another; the tide or waves, stirred to unusual depths by the wind, may gradually wear down the line of coast, or they may form shoals and coast-dunes by depositing the sand they have rolled up from the bottom of the ocean. These latter modes of action are slow in producing effects sufficiently important to be noticed in general geography, or even to be visible in the representations of coast-line laid down in ordinary maps; but they nevertheless form conspicuous features in local topography, and they are attended with consequences of great moment to the material and the moral interests of men. The forces which

---

and its accumulation at a single point, may be supposed to produce other effects than those measurable by the sounding-line. Now, almost all the operations of rural life, as I have abundantly shown, increase the liability of the soil to erosion by water. Hence, the clearing of the valley of the Ganges, for example, by man, must have much augmented the quantity of earth transported by that river to the sea, and of course have strengthened the effects, whatever they may be, of thickening the crust of the earth in the Bay of Bengal. In such cases, then, human action must rank among geological influences.

To the geological effects of the thickening of the earth's crust in the Bay of Bengal, are to be added those of thinning it on the highlands where the Ganges rises. The same action may, as a learned friend suggests to me, even have a cosmical influence. The great rivers of the earth, taken as a whole, transport sediment from the polar regions in an equatorial direction, and hence tend to increase the equatorial diameter, and at the same time, by their inequality of action, to a continual displacement of the centre of gravity, of the earth. The motion of the globe, and of all bodies affected by its attraction, is modified by every change of its form, and in this case we are not authorized to say that such effects are in any way compensated.

produce these limited results are all in a considerable degree subject to control, or rather to direction and resistance, by human power, and it is in guiding, combating, and compensating them that man has achieved some of his most remarkable and most honorable conquests over nature. The triumphs in question, or what we generally call harbor and coast improvements, whether we estimate their value by the money and labor expended upon them, or by their bearing upon the interests of commerce and the arts of civilization, must take a very high rank among the great works of man, and they are fast assuming a magnitude greatly exceeding their former relative importance. The extension of commerce and of the military marine, and especially the introduction of vessels of increased burden and deeper draught of water, have imposed upon engineers tasks of a character which a century ago would have been pronounced, and, in fact, would have been, impracticable; but necessity has stimulated an ingenuity which has contrived means of executing them, and which gives promise of yet greater performance in time to come.

Indeed, although man, detached from the solid earth, is almost powerless to struggle against the sea, he is fast becoming invincible by it so long as his foot is planted on the shore, or even on the bottom of the rolling ocean; and though on some battle-fields between the waters and the land he is obliged slowly to yield his ground, yet he retreats still facing the foe, and will finally be able to say to the sea, "Thus far shalt thou come and no farther, and here shall thy proud waves be stayed!" *

---

* It is, nevertheless, remarkable that in the particular branch of coast engineering where great improvements are most urgently needed, comparatively little has been accomplished. I refer to the creation of artificial harbors, and of facilities for loading and discharging ships. The whole coast of Italy is, one may almost say, harborless and even, wharfless, and there are many thousands of miles of coast in rich commercial countries in Europe, where vessels can neither lie in safety for a single day, nor even, in better protected havens, ship or land their passengers or cargoes except by the help of lighters, and other not less clumsy contrivances. It is strange that such enormous inconvenien-

Great Works of Material Improvement.

Men have ceased to admire the vain exercise of power which heaped up the great pyramid to gratify the pride of a despot with a giant sepulchre; for many great harbors, many important lines of internal communication, in the civilized world, now exhibit works which in volume and weight of material surpass the vastest remains of ancient architectural art, and demand the exercise of far greater constructive skill and involve a much heavier pecuniary expenditure than would now be required for the building of the tomb of Cheops. It is computed that the great pyramid, the solid contents of which when complete were about 3,000,000 cubic yards, could be erected for a million of pounds sterling. The breakwater at Cherbourg, founded in rough water sixty feet deep, at an average distance of more than two miles from the shore, contains double the mass of the pyramid, and many a comparatively unimportant canal has been constructed at twice the cost which would now build that stupendous monument.

The description of works of harbor and coast improvement which have only an economical value, not a true geographical importance, does not come within the plan of the present volume, and in treating this branch of my subject, I shall confine myself to such as are designed either to gain new soil by excluding the waters from grounds which they had permanently or occasionally covered, or to resist new encroachments of the sea upon the land.*

---

ces are borne with so little effort to remove them, and especially that breakwaters are rarely constructed by Governments except for the benefit of the military marine.

* Some notice of great works executed by man in foreign lands, and probably not generally familiar to my readers, may, however, prove not uninteresting.

The *desaguadero*, or canal constructed by the Viceroy Revillagigedo to prevent the inundation of the city of Mexico by the lakes in its vicinity, besides

Draining of Lincolnshire Fens.

The draining of the Lincolnshire fens in England, which has converted about 400,000 acres of marsh, pool, and tide-washed flat into ploughland and pasturage, is a work, or rather series of works, of great magnitude, and it possesses much economical, and, indeed, no trifling geographical, importance. Its plans and methods were, at least in part, borrowed from the example of like improvements in Holland, and it is, in difficulty and extent, inferior to works executed for the same purpose on the opposite coast of the North Sea, by Dutch, Frisic, and Low German engineers. The space I can devote to such operations will be better employed in describing the latter, and I content myself with the simple statement I have already made of the quantity of worthless and even pestilential land which has been rendered both productive and salubrious in Lincoln-

---

subsidiary works of great extent, has a cutting half a mile long, 1,000 feet wide, and from 150 to 200 feet deep.—HOFFMANN, *Encyclopædie*, art. *Mexico.*

The adit which drains the mines of Gwennap in Cornwall, with its branches, is thirty miles long. Those of the silver mines of Saxony are scarcely less extensive, and the *Ernst-August-Stollen*, or great drain of the mines of the Harz, is fifteen miles long.

The excavations for the Suez Canal were computed at 75,000,000 cubic mètres, or about 100,000,000 cubic yards, and those of the Ganges Canal, which, with its branches, had a length of 3,000 miles, amount to nearly the same quantity.

The quarries at Maestricht have undermined a space of sixteen miles by six, or more than two American townships, and the catacombs of Rome, in part, at least, originally quarries, have a lineal extent of five hundred and fifty miles. The catacombs of Paris required the excavation of 13,000,000 cubic yards of stone, or more than four times the volume of the great pyramid.

The excavations for the Mt. Cenis tunnel, eight miles in length, wholly through solid rock, amounted to more than 900,000 cubic yards, and 16,000,000 of brick were employed for the lining.

In an article on recent internal improvements in England, in the London Quarterly Review for January, 1858, it is stated that in a single rock-cutting on the Liverpool and Manchester railway, 480,000 cubic yards of stone were shire, by diking out the sea, and the rivers which traverse the fens of that country.

The almost continued prevalence of west winds upon both coasts of the German Ocean occasions a constant set of the currents of that sea to the east, and both for this reason and on account of the greater violence of storms from the former quarter, the English shores of the North Sea are less exposed to invasion by the waves than those of the Netherlands and the provinces contiguous to them on the north. The old Netherlandish chronicles are filled with the most startling accounts of the damage done by the irruptions of the ocean, from west winds or extraordinarily high tides, at times long before any considerable extent of seacoast was diked. Several hundreds of these terrible inundations are recorded, and in many of them the loss of human lives is estimated as high as one hundred thousand. It is impossible to doubt that there must be enormous exaggeration in these numbers; for, with all the reckless hardihood shown by men in braving the dangers and priva-

---

removed; that the earth excavated in the construction of English railways up to that date amounted to a hundred and fifty million cubic yards, and that at the Round Down Cliff, near Dover, a single blast of nineteen thousand pounds of powder blew down a thousand million tons of chalk, and covered fifteen acres of land with the fragments.

In 1869, a mass of marble equal to one and a half times the cubical contents of the Duomo at Florence, or about 450,000 cubic yards, was thrown down at Carrara by one blast, and two hours after, another equal mass, which had been loosened by the explosion, fell of itself.—ZOLFANELLI, *La Lunigiana*, p. 43.

The coal yearly extracted from the mines of England averages not less than 100,000,000 tons. The specific gravity of British coal ranges from 1.20 to 1.35, and consequently we may allow a cubic yard to the ton. If we add the earth and rock removed in order to reach the coal, we shall have a yearly amount of excavation for this one object equal to more than thirty times the volume of the pyramid of Cheops.

These are wonderful achievements of human industry; but the rebuilding of Chicago within a single year after the great fire—not to speak of the extraordinary material improvements previously executed at that city—surpasses them all, and it probably involved the expenditure of a sum of muscular and of moral energy which has never before been exerted in the accomplishment of a single material object, within a like period.

tions attached by nature to their birthplace, it is inconceivable that so dense a population as such wholesale destruction of life supposes could find the means of subsistence, or content itself to dwell, on a territory liable, a dozen times in a century, to such fearful devastation. There can be no doubt, however, that the low continental shores of the German Ocean very frequently suffered immense injury from inundation by the sea, and it is natural, therefore, that the various arts of resistance to the encroachments of the ocean, and, finally, of aggressive warfare upon its domain, and of permanent conquest of its territory, should have been earlier studied and carried to higher perfection in the latter countries, than in England, which had less to lose or to gain by the incursions or the retreat of the waters.

Indeed, although the confinement of swelling rivers by artificial embankments is of great antiquity, I do not know that the defence or acquisition of land from the sea by diking was ever practised on a large scale until systematically undertaken by the Netherlanders, a few centuries after the commencement of the Christian era. The silence of the Roman historians affords a strong presumption that this art was unknown to the inhabitants of the Netherlands at the time of the Roman invasion, and the elder Pliny's description of the mode of life along the coast which has now been long diked in, applies precisely to the habits of the people who live on the low islands and mainland flats lying outside of the chain of dikes, and wholly unprotected by embankments of any sort.

Origin of Sea-dikes.

It has been conjectured, and not without probability, that the causeways built by the Romans across the marshes of the Low Countries, in their campaigns against the Germanic tribes, gave the natives the first hint of the utility which might be derived from similar constructions applied to a different purpose.* If this is so, it is one of the most interesting among the many instances in which the arts and enginery of war have been so modified as to be eminently promotive of the blessings of peace, thereby in some measure compensating the wrongs and sufferings they have inflicted on humanity.[*] The Lowlanders are

---

* It has often been alleged by eminent writers that a part of the fens in Lincolnshire was reclaimed by sea-dikes under the government of the Ro-

---

mans. I have found no ancient authority in support of this assertion, nor can I refer to any passage in Roman literature in which sea-dikes are expressly mentioned otherwise than as walls or piers, except that in Pliny (*Hist. Nat.*, xxxvi. 24), where it is said that the Tyrrhenian Sea was excluded from the Lucrine Lake by dikes. Dugdale, whose enthusiasm for his subject led him to believe that recovering from the sea land subject to be flooded by it, was of divine appointment, because God said: "Let the waters under the heaven be gathered together unto one place and let the dry land appear," unhesitatingly ascribes the reclamation of the Lincolnshire fens to the Romans, though he is able to cite but one authority, a passage in Tacitus's Life of Agricola, which certainly has no such meaning, in support of the assertion.—*History of Embankment and Drainage*, 2d edition, 1772.

[*] It is worth mentioning, as an illustration of the applicability of military instrumentalities to pacific art, that the sale of gunpowder in the United States was smaller during the late rebellion than before, because the war caused the suspension of many public and private improvements, in the execution of which great quantities of powder were used for blasting.

The same observation was made in France during the Crimean war, and it is alleged that, in general, not ten per cent. of the powder manufactured on either side of the Atlantic is employed for military purposes.

The blasting for the Mount Cenis tunnel consumed gunpowder enough to fill more than 200,000,000 musket cartridges.

It is a fact not creditable to the moral sense of modern civilization, that very many of the most important improvements in machinery and the working of metals have originated in the necessities of war, and that man's highest ingenuity has been shown, and many of his most remarkable triumphs over natural forces achieved, in the contrivance of engines for the destruction of his fellow-man. The military material employed by the first Napoleon has become, in less than two generations, nearly as obsolete as the sling and stone of the shepherd, and attack and defence now begin at distances to which, half a century ago, military reconnoissances hardly extended. Upon a partial view of the subject, the human race seems destined to become its own executioner—on the one hand, exhausting the capacity of the earth to furnish sustenance to her taskmaster; on the other, compensating diminished production by inventing more efficient methods of exterminating the consumer. At the present moment, at an epoch of universal peace, the whole civilized world, with the happy exception of our own country, is devoting its utmost enerbelieved to have secured some coast and bay islands by ring-dikes, and to have embanked some fresh-water channels, as early as the eighth or ninth century; but it does not appear that sea-dikes, important enough to be noticed in historical records, were constructed on the mainland before the thirteenth century. The practice of draining inland accumulations of water, whether fresh or salt, for the purpose of bringing under cultivation the ground they cover, is of later origin, and is said not to have been adopted until after the middle of the fifteenth century.*

Gain and Loss of Land in the Netherlands.

The total amount of surface gained to the agriculture of the Netherlands by diking out the sea and by draining shallow bays and lakes, is estimated by Staring at three hundred and fifty-five thousand *bunder* or hectares, equal to eight hundred and seventy-seven thousand two hundred and forty acres, which is one-tenth of the area of the kingdom.† In very many instances the dikes have been partially, in some particularly exposed localities totally, destroyed by the violence of the sea, and the drained lands again flooded. In some cases the soil thus pain-

---

gies, applying the highest exercise of inventive genius, to the production of new engines of war; and the late extraordinary rise in the price of iron and copper is in great part due to the consumption of those metals in the fabrication of arms and armed vessels. The simple substitution of sheet-copper for paper and other materials in the manufacture of cartridges has increased the market-price of copper by a large percentage on its former cost.

But war develops great civil virtues, and brings into action a degree and kind of physical energy which seldom fails to awaken a new intellectual life in a people that achieves great moral and political results through great heroism and endurance and perseverance. Domestic corruption has destroyed more nations than foreign invasion, and a people is rarely conquered till it has deserved subjugation.

* STARING, *Voormaals en Thans*, p. 150.

† Idem, p. 163. Much the largest proportion of the lands so reclaimed, though for the most part lying above low-water tidemark, are at a lower level than the Lincolnshire fens, and more subject to inundation from the irruptions of the sea.

fully won from the ocean has been entirely lost; in others it has been recovered by repairing or rebuilding the dikes and pumping out the water. Besides this, the weight of the dikes gradually sinks them into the soft soil beneath, and this loss of elevation must be compensated by raising the surface, while the increased burden thus added tends to sink them still lower. "Tetens declares," says Kohl, "that in some places the dikes have gradually sunk to the depth of sixty or even a hundred feet."* For these reasons, the processes of dike-building have been almost everywhere again and again repeated, and thus the total expenditure of money and of labor upon the works in question is much greater than would appear from an estimate of the actual cost of diking-in a given extent of coast-land and draining a given area of water-surface.†

Loss of Land by Incursions of Sea.

On the other hand, by erosion of the coast-line, the drifting of sand-dunes into the interior, and the drowning of fens and morasses by incursions of the sea—all caused, or at least greatly aggravated, by human improvidence—the Netherlands have lost a far larger area of land since the commencement of the Christian era than they have gained by diking and draining. Staring despairs of the possibility of calculating the loss from the first-mentioned two causes of destruction, but he estimates that not less than six hundred and forty thousand bunder, or one million five hundred and eighty-one thousand acres, of fen and marsh have been washed away, or rather deprived of their vegetable surface and covered by water; and thirty-seven thousand bunder, or ninety-one thousand four hundred acres, of recovered land, have been lost by the destruction of the dikes which protected them.* The average value of land gained from the sea is estimated at about nineteen pounds sterling, or ninety dollars, per acre; while the lost fen and morass was not worth more than one twenty-fifth part of the same price. The ground buried by the drifting of the dunes appears to have been almost entirely of this latter character, and, upon the whole, there is no doubt that the soil added by human industry to the territory of the Netherlands, within the historical period, greatly exceeds in pecuniary value that which has fallen a prey to the waves during the same era.

---

* *Die Inseln und Marschen der Herzogthümer Schleswig und Holstein*, iii., p. 151.

† The purely agricultural island of Pelworm, off the coast of Schleswig, containing about 10,000 acres, annually expends for the maintenance of its dikes not less than £6,000 sterling, or nearly $30,000.—J. G. KOHL, *Inseln und Marschen Schleswig's und Holstein's*, ii., p. 394.

The original cost of the dikes of Pelworm is not stated.

"The greatest part of the province of Zeeland is protected by dikes measuring 250 miles in length, the maintenance of which costs, in ordinary years, more than a million guilders [above $400,000]. . . . The annual expenditure for dikes and hydraulic works in Holland is from five to seven million guilders" [$2,000,000 to $2,800,000].—WILD, *Die Niederlande*, i., p. 62.

One is not sorry to learn that the Spanish tyranny in the Netherlands had some compensations. The great chain of ring-dikes which surrounds a large part of Zeeland is due to the energy of Caspar de Robles, the Spanish governor of that province, who in 1570 ordered the construction of these works at the public expense, as a substitute for the private embankments which had previously partially served the same purpose.—WILD, *Die Niederlande*, i., p. 62.

Upon most low and shelving coasts, like those of the Netherlands, the maritime currents are constantly changing, in consequence of the variability of the winds, and the shifting of the sand-banks, which the currents themselves now form and now displace. While, therefore, at one point the sea is advancing landward, and requiring great effort to prevent the undermining and washing away of the dikes, it is shoaling at another by its own deposits, and exposing, at low water, a gradually widening belt of sands and ooze. The coast-lands selected for diking-in are always at points where the sea is depositing productive soil. The Eider, the Elbe, the Weser, the Ems, the Rhine, the Maas, and the Schelde bring down large quantities of fine earth. The prevalence of west winds prevents the waters from carrying this material far out from the coast, and it is at last deposited northward or southward from the mouth of the rivers which contribute it, according to the varying drift of the currents.

---

* STARING, *Voormaals en Thans*, p. 163.

Marine Deposits.

The process of natural deposit which prepares the coast for diking-in is thus described by Staring: "All sea-deposited soil is composed of the same constituents. First comes a stratum of sand, with marine shells, or the shells of mollusks living in brackish water. If there be tides, and, of course, flowing and ebbing currents, mud is let fall upon the sand only after the latter has been raised above low-water mark; for then only, at the change from flood to ebb, is the water still enough to form a deposit of so light a material. Where mud is found at great depths, as, for example, in a large proportion of the Ij, it is a proof that at this point there was never any considerable tidal flow or other current. . . . The powerful tidal currents, flowing and ebbing twice a day, drift sand with them. They scoop out the bottom at one point, raise it at another, and the sand-banks in the current are continually shifting. As soon as a bank raises itself above low-water mark, flags and reeds establish themselves upon it. The mechanical resistance of these plants checks the retreat of the high water and favors the deposit of the earth suspended in it, and the formation of land goes on with surprising rapidity. When it has risen to high-water level, it is soon covered with grasses, and becomes what is called *schor* in Zeeland, *kwelder* in Friesland. Such grounds are the foundation or starting-point of the process of diking. When they are once elevated to the flood-tide level, no more mud is deposited upon them except by extraordinary high tides. Their further rise is, accordingly, very slow, and it is seldom advantageous to delay longer the operation of diking."[*]

---

[*] *Voormaals en Thans*, pp. 150, 151. According to Reventlov, *conferva* first appear at the bottom in shoal water, then, after the deposit has risen above the surface, *Salicornia herbacea*. The *Salicornia* is followed by various sand-plants, and so the ground rises, by *Poa distans* and *Poa maritum*, and finally common grasses establish themselves.—*Om Markdannelsen poa Vestkysten af Slesvig*, pp. 7, 8.

Sea-dikes of the Netherlands.

The formation of new banks by the sea is constantly going on at points favorable for the deposit of sand and earth, and hence opportunity is continually afforded for enclosure of new land outside of that already diked in, the coast is fast advancing seaward, and every new embankment increases the security of former enclosures. The province of Zeeland consists of islands washed by the sea on their western coasts, and separated by the many channels through which the Schelde and some other rivers find their way to the ocean. In the twelfth century these islands were much smaller and more numerous than at present. They have been gradually enlarged, and, in several instances, at last connected by the extension of their system of dikes. Walcheren is formed of ten islets united into one about the end of the fourteenth century. At the middle of the fifteenth century, Goeree and Overflakkee consisted of separate islands, containing altogether about ten thousand acres; by means of above sixty successive advances of the dikes, they have been brought to compose a single island, whose area is not less than sixty thousand acres.*

In the Netherlands—which the first Napoleon characterized as a deposit of the Rhine, and as, therefore, by natural law, rightfully the property of him who controlled the sources of that great river—and on the adjacent Frisic, Low German, and Danish shores and islands, sea and river dikes have been constructed on a grander and more imposing scale than in any other country. The whole economy of the art has been there most thoroughly studied, and the literature of the subject is very extensive. For my present aim, which is concerned with results rather than with processes, it is not worth while to refer to professional treatises, and I shall content myself with presenting such information as can be gathered from works of a more popular character.

---

* STARING, *Voormaals en Thans*, p. 152. Kohl states that the peninsula of Diksand on the coast of Holstein consisted, at the close of the last century, of several islands measuring together less than five thousand acres. In 1837 they had been connected with the mainland, and had nearly doubled in area. —*Inseln u. Marschen Schlesw. Holst.*, iii., p. 262.

The superior strata of the lowlands upon and near the coast are, as we have seen, principally composed of soil brought down by the great rivers I have mentioned, and either directly deposited by them upon the sands of the bottom, or carried out to sea by their currents, and then, after a shorter or longer exposure to the chemical and mechanical action of salt-water and marine currents, restored again to the land by tidal overflow and subsidence from the waters in which it was suspended. At a very remote period the coast-flats were, at many points, raised so high by successive alluvious or tidal deposits as to be above ordinary high-water level, but they were still liable to occasional inundation from river-floods, and from the seawater also, when heavy or long-continued west winds drove it landwards. The extraordinary fertility of this soil and its security as a retreat from hostile violence attracted to it a considerable population, while its want of protection against inundation exposed it to the devastations of which the chroniclers of the Middle Ages have left such highly colored pictures. The first permanent dwellings on the coast-flats were erected upon artificial mounds, and many similar precarious habitations still exist on the unwalled islands and shores beyond the chain of dikes. River embankments, which, as is familiarly known, have from the earliest antiquity been employed in many countries where sea-dikes are unknown, were probably the first works of this character constructed in the Low Countries, and when two neighboring streams of fresh water had been embanked, the next step in the process would naturally be to connect the river-walls together by a transverse dike or raised causeway, which would serve as a means of communication between different hamlets and at the same time secure the intermediate ground both against the backwater of river-floods and against overflow by the sea. The oldest true sea-dikes described in historical records, however, are those enclosing islands in the estuaries of the great rivers, and it is not impossible that the double character they possess as a security against maritime floods and as a military rampart, led to their adoption upon those islands before similar constructions had been attempted upon the mainland.

At some points of the coast, various contrivances, such as piers, piles, and, in fact, obstructions of all sorts to the ebb of the current, are employed to facilitate the deposit of slime, before a regular enclosure is commenced. Usually, however, the first step is to build low and cheap embankments, extending from an older dike, or from high ground, around the parcel of flat intended to be secured. These are called summer dikes. They are erected when a sufficient extent of ground to repay the cost has been elevated enough to be covered with coarse vegetation fit for pasturage. They serve both to secure the ground from overflow by the ordinary flood-tides of mild weather, and to retain the slime deposited by very high water, which would otherwise be partly carried off by the retreating ebb. The elevation of the soil goes on slowly after this; but when it has at last been sufficiently enriched, and raised high enough to justify the necessary outlay, permanent dikes are constructed by which the water is excluded at all seasons. These embankments are constructed of sand from the coast-dunes or from sand-banks, and of earth from the mainland or from flats outside the dikes, bound and strengthened by fascines, and provided with sluices, which are generally founded on piles and of very expensive construction, for drainage at low water. The outward slope of the sea-dikes is gentle, experience having shown that this form is least exposed to injury both from the waves and from floating ice, and the most modern dikes are even more moderate in the inclination of the seaward scarp than the older ones.* The crown of the dike, however, for the last three or four feet of its height, is much steeper, being intended rather as a protection against the spray than against the waves, and the inner slope is always comparatively abrupt.

---

* The inclination varies from one foot rise in four of base to one foot in fourteen.—KOHL, iii., p. 210.

The height and thickness of dikes varies according to the elevation of the ground they enclose, the rise of the tides, the direction of the prevailing winds, and other special causes of exposure, but it may be said that they are, in general, raised from fifteen to twenty feet above ordinary high-water mark. The water-slopes of river-dikes are protected by plantations of willows or strong semi-aquatic shrubs or grasses, but as these will not grow upon banks exposed to salt-water, sea-dikes must be faced with stone, fascines, or some other *revêtement.*[*] Upon the coast of Schleswig and Holstein, where the people have less capital at their command, they defend their embankments against ice and the waves by a coating of twisted straw or reeds, which must be renewed as often as once, sometimes twice a year. The inhabitants of these coasts call the chain of dikes "the golden border," a name it well deserves, whether we suppose it to refer to its enormous cost, or, as is more probable, to its immense value as a protection to their fields and their firesides.

When outlying flats are enclosed by building new embankments, the old interior dikes are suffered to remain, both as an additional security against the waves, and because the removal of them would be expensive. They serve, also, as roads or causeways, a purpose for which the embankments nearest the sea are seldom employed, because the whole structure might be endangered from the breaking of the turf by wheels and the hoofs of horses. Where successive rows of dikes have been thus constructed, it is observed that the ground defended by the more ancient embankments is lower than that embraced within the newer enclosures, and this depression of level has been ascribed to a general subsidence of the coast from geological causes;* but the better opinion seems to be that it is, in most cases, due merely to the consolidation and settling of the earth from being more effectually dried, from the weight of the dikes, from the tread of men and cattle, and from the movement of the heavy wagons which carry off the crops.†

---

[*] The dikes are sometimes founded upon piles, and sometimes protected by one or more rows of piles driven deeply down into the bed of the sea in front of them. "Triple rows of piles of Scandinavian pine," says Wild, "have been driven down along the coast of Friesland, where there are no dunes, for a distance of one hundred and fifty miles. The piles are bound together by strong cross-timbers and iron clamps, and the interstices filled with stones. The ground adjacent to the piling is secured with fascines, and at exposed points heavy blocks of stone are heaped up as an additional protection. The earth-dike is built behind the mighty bulwark of this breakwater, and its foot also is fortified with stones." . . . . "The great Helder dike is about five miles long and forty feet wide at the top, along which runs a good road. It slopes down two hundred feet into the sea, at an angle of forty degrees. The highest waves do not reach the summit, the lowest always cover its base. At certain distances, immense buttresses, of a height and width proportioned to those of the dike, and even more strongly built, run several hundred feet out into the rolling sea. This gigantic artificial coast is entirely composed of Norwegian granite."—WILD, *Die Niederlande*, i., pp. 61, 62.

---

* A similar subsidence of the surface is observed in the diked ground of the Lincolnshire fens, where there is no reason to suspect a general depression from geological causes.

† The shaking of the ground, even when loaded with large buildings, by the passage of heavy carriages or artillery, or by the march of a body of cavalry or even infantry, shows that such causes may produce important mechanical effects on the condition of the soil. The bogs in the Netherlands, as in most other countries, contain large numbers of fallen trees, buried to a certain depth by earth and vegetable mould. When the bogs are dry enough to serve as pastures, it is observed that trunks of these ancient trees rise of themselves to the surface. Staring ascribes this singular phenomenon to the agitation of the ground by the tread of cattle. "When roadbeds," observes he, "are constructed of gravel and pebbles of different sizes, and these latter are placed at the bottom without being broken and rolled hard together, they are soon brought to the top by the effect of travel on the road. Lying loosely, they undergo some motion from the passage of every wagon-wheel and the tread of every horse that passes over them. This motion is an oscillation or partial rolling, and as one side of a pebble is raised, a little fine sand or earth is forced under it, and the frequent repetition of this process by cattle or carriages moving in opposite directions brings it at last to the surface. We may suppose that a similar effect is produced on the stems of trees in the bogs by the tread of animals."—*De Bodem van Nederland*, i., pp. 75, 76.

It is observed in the Northern United States, that when soils containing

Notwithstanding this slow sinking, most of the land enclosed by dikes is still above low-water mark, and can, therefore, be wholly or partially freed from rain-water, and from that received by infiltration from higher ground, by sluices opened at the ebb of the tide. For this purpose the land is carefully ditched, and advantage is taken of every favorable occasion for discharging the water through the sluices. But the ground cannot be effectually drained by this means, unless it is elevated four or five feet, at least, above the level of the ebb-tide, because the ditches would not otherwise have a sufficient descent to carry the water off in the short interval between ebb and flow, and because the moisture of the saturated subsoil is always rising by capillary attraction. Whenever, therefore, the soil has sunk below the level I have mentioned, and in

---

pebbles are cleared and cultivated, and the stones removed from the surface, new pebbles, and even bowlders of many pounds weight, continue to show themselves above the ground, every spring, for a long series of years. In clayey soils the fence-posts are thrown up in a similar way, and it is not uncommon to see the lower rail of a fence thus gradually raised a foot or even two feet above the ground. This rising of stones and fences is popularly ascribed to the action of the severe frosts of that climate. The expansion of the ground, in freezing, it is said, raises its surface, and, with the surface, objects lying near or connected with it. When the soil thaws in the spring, it settles back again to its former level, while the pebbles and posts are prevented from sinking as low as before by loose earth which has fallen under them. The fact that the elevation spoken of is observed only in the spring, gives countenance to this theory, which is perhaps applicable also to the cases stated by Staring, and it is probable that the two causes above assigned concur in producing the effect.

The question of the subsidence of the Netherlandish coast has been much discussed. Not to mention earlier geologists, Venema, in several essays, and particularly in *Het Dalen van de Noordelijke Kuststreken van ons Land*, 1854, adduces many facts and arguments to prove a slow sinking of the northern provinces of Holland. Laveleye (*Affaissement du sol et envasement des fleuves survenus dans les temps historiques*, 1859), upon a still fuller investigation, arrives at the same conclusion. The eminent geologist Staring, however, who briefly refers to the subject in *De Bodem van Nederland*, i., p. 356 *et seqq.*, does not consider the evidence sufficient to prove anything more than the sinking of the surface of the polders from drying and consolidation.—See ELISÉE RECLUS, *La Terre*, vol. i., pp. 730, 732.

cases where its surface has never been raised above it, pumps, worked by wind or some other mechanical power, must be very frequently employed to keep the land dry enough for pasturage and cultivation.*

Draining of the Lake of Haarlem.

The substitution of steam-engines for the feeble and uncertain action of windmills, in driving pumps, has much facilitated the removal of water from the polders as well as the draining of lakes, marshes, and shallow bays, and thus given such an impulse to these enterprises, that not less than one hundred and ten thousand acres were reclaimed from the waters, and added to the agricultural domain of the Netherlands, between 1815 and 1858. The most important of these undertakings was the draining of the Lake of Haarlem, and for this purpose some of the most powerful hydraulic engines ever constructed were designed and executed.† The origin of this lake is unknown. It is supposed by some geographers to be a part of an ancient bed of the Rhine, the channel of which, as there is good reason to believe, has undergone great changes since the Roman invasion of the Netherlands; by others it is thought to have once formed an inland marine channel, separated from the sea by a chain of low islands, which the sand washed up by the tides has since connected with the mainland and converted into a continuous line of coast. The best authorities, however, find geological evidence that the surface occupied by the lake was originally a marshy tract containing within its limits little solid ground, but many ponds and inlets, and much floating as well as fixed fen.

---

* The elevation of the lands enclosed by dikes—or *polders*, as they are called in Holland—above low-water mark, depends upon the height of the tides, or, in other words, upon the difference between ebb and flood. The tide cannot deposit earth higher than it flows, and after the ground is once enclosed, the decay of the vegetables grown upon it and the addition of manures do not compensate the depression occasioned by drying and consolidation. On the coast of Zeeland and the islands of South Holland, the tides, and of course the surface of the lands deposited by them, are so high that the polders can be drained by ditching and sluices, but at other points, as in the enclosed grounds of North Holland on the Zuiderzee, where the tide rises but three feet or even less, pumping is necessary from the beginning. —STARING, *Voormaals en Thans*, p. 152.

† The principal engine, of 500 horse-power, drove eleven pumps with a total delivery of 31,000 cubic yards per hour.—WILD, *Die Nederlande*, i., p. 87.

In consequence of the cutting of turf for fuel, and the destruction of the few trees and shrubs which held the loose soil together with their roots, the ponds are supposed to have gradually extended themselves, until the action of the wind upon their enlarged surface gave their waves sufficient force to overcome the resistance of the feeble barriers which separated them, and to unite them all into a single lake. Popular tradition, it is true, ascribes the formation of the Lake of Haarlem to a single irruption of the sea, at a remote period, and connects it with one or another of the destructive inundations of which the Netherland chronicles describe so many; but on a map of the year 1531, a chain of four smaller waters occupies nearly the ground afterwards covered by the Lake of Haarlem, and they have most probably been united by gradual encroachments resulting from the improvident practices above referred to, though no doubt the consummation may have been hastened by floods, and by the neglect to maintain dikes, or the intentional destruction of them, in the long wars of the sixteenth century.

The Lake of Haarlem was a body of water not far from fifteen miles in length, by seven in greatest width, lying between the cities of Amsterdam and Leyden, running parallel with the coast of Holland at the distance of about five miles from the sea, and covering an area of about 45,000 acres. By means of the Ij, it communicated with the Zuiderzee, the Mediterranean of the Netherlands, and its surface was little above the mean elevation of that of the sea. Whenever, therefore, the waters of the Zuiderzee were acted upon by strong north-west winds, those of the Lake of Haarlem were raised proportionally and driven southwards, while winds from the south tended to create a flow in the opposite direction. The shores of the lake were everywhere low, and though between the years 1767 and 1848 more than $1,700,000 had been expended in checking its encroachments, it often burst its barriers, and produced destructive inundations. In November, 1836, a south wind brought its waters to the very gates of Amsterdam, and in December of the same year, in a north-west gale, they overflowed twenty thousand acres of land at the southern extremity of the lake, and flooded a part of the city of Leyden. The depth of water in the lake did not, in general, exceed fourteen feet, but the bottom was a semi-fluid ooze or slime, which partook of the agitation of the waves, and added considerably to their mechanical force. Serious fears were entertained that the lake would form a junction with the inland waters of the Legmeer and Mijdrecht, swallow up a vast extent of valuable soil, and finally endanger the security of a large proportion of the land which the industry of Holland had gained in the course of centuries from the ocean.

For this reason, and for the sake of the large addition the bottom of the lake would make to the cultivable soil of the state, it was resolved to drain it, and the preliminary steps for that purpose were commenced in the year 1840. The first operation was to surround the entire lake with a ring-canal and dike, in order to cut off the communication with the Ij, and to exclude the water of the streams and morasses which discharged themselves into it from the land side. The dike was composed of different materials, according to the means of supply at different points, such as sand from the coast-dunes, earth and turf excavated from the line of the ring-canal, and floating turf,* fascines being everywhere used to bind and compact the mass together. This operation was completed in 1848, and three steam-pumps were then employed for five years in discharging the water. The whole enterprise was conducted at the expense of the state, and in 1853 the recovered lands were offered for sale for its benefit. Up to 1858, forty-two thousand acres had been sold at not far from sixteen pounds sterling or

---

* In England and New England, where the marshes have been already drained or are of comparatively small extent, the existence of large floating islands seems incredible, and has sometimes been treated as a fable, but no geographical fact is better established. Kohl (*Inseln und Marschen Schleswig-Holsteins*, iii., p. 309) reminds us that Pliny mentions among the wonders

---

of Germany the floating islands, covered with trees, which met the Roman fleets at the mouths of the Elbe and the Weser. Our author speaks also of having visited, in the territory of Bremen, floating moors, bearing not only houses but whole villages. At low stages of the water these moors rest upon a bed of sand, but are raised from six to ten feet by the high water of spring, and remain afloat until, in the course of the summer, the water beneath is exhausted by evaporation and drainage, when they sink down upon the sand again.

Staring explains, in an interesting way, the whole growth, formation, and functions of floating fens or bogs, in his very valuable work, *De Bodem van Nederland*, i., pp. 36–43. The substance of his account is as follows: The first condition for the growth of the plants which compose the substance of turf and the surface of the fens, is stillness of the water. Hence they are not found in running streams, nor in pools so large as to be subject to frequent agitation by the wind. For example, not a single plant grew in the open part of the Lake of Haarlem, and fens cease to form in all pools as soon as, by the cutting of the turf for fuel or other purposes, their area is sufficiently enlarged to be much acted on by wind. When still water above a yard deep is left undisturbed, aquatic plants of various genera, such as Nuphar, Nymphæa, Limnanthemum, Stratiotes, Polygonum, and Potamogeton, fill the bottom with roots and cover the surface with leaves. Many of the plants die every year, and prepare at the bottom a soil fit for the growth of a higher order of vegetation, Phragmites, Acorus, Sparganium, Rumex, Lythrum, Pedicularis, Spiræa, Polystichum, Comarum, Caltha, etc., etc. In the course of twenty or thirty years the muddy bottom is filled with roots of aquatic and marsh plants, which are lighter than water, and if the depth is great enough to give room for detaching this vegetable network, a couple of yards for example, it rises to the surface, bearing with it, of course, the soil formed above it by decay of stems and leaves. New genera now appear upon the mass, such a Carex, Menyanthes, and others, and soon thickly cover it. The turf has now acquired a thickness of from two to four feet, and is called in Groningen *lad;* in Friesland, *til*, *tilland*, or *drijftil;* in Overijssel, *krag;* and in Holland, *rietzod*. It floats about as driven by the wind, gradually increasing in thickness by the decay of its annual crops of vegetation, and in about half a century reaches the bottom and becomes fixed. If it has not been invaded in the meantime by men or cattle, trees and arborescent seventy-seven dollars an acre, amounting altogether to £661,000 sterling or $3,200,000. The unsold lands were valued at more than £6,000 or nearly $30,000, and as the total cost was £764,500 or about $3,700,000, the direct loss to the state, exclusive of interest on the capital expended, may be stated at £100,000 or something less than $500,000.

The success of this operation has encouraged others of like

---

plants, Alnus, Salix, Myrica, etc., appear, and these contribute to hasten the attachment of the turf to the bottom, both by their weight and by sending their roots quite through into the ground."

This is the regular method employed by nature for the gradual filling up of shallow lakes and pools, and converting them first into morass and then into dry land. Whenever, therefore, man removes the peat or turf, he exerts an injurious geographical agency, and, as I have already said, there is no doubt that the immense extension of the inland seas of Holland in modern times is owing to this and other human imprudences. "Hundreds of hectares of floating pastures," says our author, "which have nothing in their appearance to distinguish them from grass-lands resting on solid bog, are found in Overijssel, in North Holland, and near Utrecht. In short, they occur in all deep bogs, and wherever deep water is left long undisturbed."

In one case a floating island, which had attached itself to the shore, continued to float about for a long time after it was torn off by a flood, and was solid enough to keep a pond of fresh water upon it sweet, though the water in which it was swimming had become brackish from the irruption of the sea. After the hay is cut, cattle are pastured, and occasionally root-crops grown upon these islands, and they sometimes have large trees growing upon them.

When the turf or peat has been cut, leaving water less than a yard deep, Equisetum limosum grows at once, and is followed by the second class of marsh plants mentioned above. Their roots do not become detached from the bottom in such shallow water, but form ordinary turf or peat. These processes are so rapid that a thickness of from three to six feet of turf is formed in half a century, and many men have lived to mow grass where they had fished in their boyhood, and to cut turf twice in the same spot. In Ireland the growth of peat is said to be much more rapid. ELISÉE RECLUS, *La Terre*, i., 591, 592. But see ASBJÖRNSEN, *Torv og Torvdrift*, ii., 29, 30.

Captain Gilliss says that before Lake Taguatagua in Chili was drained, there were in it islands composed of dead plants matted together to a thickness of from four to six feet, and with trees of medium size growing upon them. These islands floated before the wind "with their trees and browsing cattle." —*United States Naval Astronomical Expedition to the Southern Hemisphere*, i., pp. 16, 17.

nature in Holland. The Zuid Plas, which covered 11,500 acres, and was two feet deeper than the Lake of Haarlem, has been drained, and a similar work now in course of execution on an arm of the Scheld, will recover about 35,000 acres.

In a country like the United States, of almost boundless extent of sparsely inhabited territory, such an expenditure for such an object would be poor economy. But Holland has a narrow domain, great pecuniary resources, an excessively crowded population, and a consequent need of enlarged room and opportunity for the exercise of industry. Under such circumstances, and especially with an exposure to dangers so formidable, there is no question of the wisdom of the measure. It has already provided homes and occupation for more than five thousand citizens, and furnished a profitable investment for a private capital of not less than £400,000 sterling or $2,000,000, which has been expended in improvements over and above the purchase money of the soil; and the greater part of this sum, as well as of the cost of drainage, has been paid as a compensation for labor. The excess of governmental expenditure over the receipts, if employed in constructing ships of war or fortifications, would have added little to the military strength of the kingdom; but the increase of territory, the multiplication of homes and firesides which the people have an interest in defending, and the augmentation of agricultural resources, constitute a stronger bulwark against foreign invasion than a ship of the line or a fortress armed with a hundred cannon.

Draining of the Zuiderzee.

I have referred to the draining of the Lake of Haarlem as an operation of great geographical as well as economical and mechanical interest. A much more gigantic project, of a similar character, is now engaging the attention of the Netherlandish engineers. It is proposed to drain the great salt-water basin called the Zuiderzee. This inland sea covers an area of not less than two thousand square miles, or about one million three hundred thousand acres. The seaward half, or that portion lying north-west of a line drawn from Enkhuizen to Staveren, is believed to have been converted from a marsh to an open bay since the fifth century after Christ, and this change is ascribed, partly if not wholly, to the interference of man with the order of nature. The Zuiderzee communicates with the sea by at least six considerable channels, separated from each other by low islands, and the tide rises within the basin to the height of three feet. To drain the Zuiderzee, these channels must first be closed and the passage of the tidal flood through them cut off. If this be done, the coast currents will be restored approximately to the lines they followed fourteen or fifteen centuries ago, and there can be little doubt that an appreciable effect will thus be produced upon all the tidal phenomena of that coast, and, of course, upon the maritime geography of Holland.

A ring-dike and canal must then be constructed around the landward side of the basin, to exclude and carry off the fresh-water streams which now empty into it. One of these, the Ijssel, a considerable river, has a course of eighty miles, and is, in fact, one of the outlets of the Rhine, though augmented by the waters of several independent tributaries. These preparations being made, and perhaps transverse dikes erected at convenient points for dividing the gulf into smaller portions, the water must be pumped out by machinery, in substantially the same way as in the case of the Lake of Haarlem.* No safe calculations can be made as to the expenditure of time and money required for the execution of this stupendous enterprise, but I believe its practicability is not denied by competent judges, though doubts are entertained as to its financial expediency.* The geographical results of this improvement would be analogous to those of the draining of the Lake of Haarlem, but many times multiplied in extent, and its meteorological effects, though perhaps not perceptible on the coast, could hardly fail to be appreciable in the interior of Holland.

---

* The dependence of man upon the aid of spontaneous nature, in his most arduous material works, is curiously illustrated by the fact that one of the most serious difficulties to be encountered in executing this gigantic scheme is that of procuring brushwood for the fascines to be employed in the embankments. See Diggelen's pamphlet, "*Groote Werken in Nederland.*"

The bearing of the works I have noticed, and of others similar in character, upon the social and moral, as well as the purely economical, interests of the people of the Netherlands, has induced me to describe them more in detail than the general purpose of this volume may be thought to justify; but if we consider them simply from a geographical point of view, we shall find that they are possessed of no small importance as modifications of the natural condition of terrestrial surface. There is good reason to believe that before the establishment of a partially civilized race upon the territory now occupied by Dutch, Frisic, and Low German communities, the grounds not exposed to inundation were overgrown with dense woods; that the lowlands between these forests and the sea-coasts were marshes, covered and partially solidified by a thick matting of peat-plants and shrubs interspersed with trees; and that even the sand-dunes of the shore were protected by a vegetable growth which, in a great measure, prevented the drifting and translocation of them.

The present causes of river and coast erosion existed, indeed, at the period in question; but some of them must have acted with less intensity, there were strong natural safeguards against the influence of marine and fresh-water currents, and the conflicting tendencies had arrived at a condition of approximate equilibrium, which permitted but slow and gradual changes in the face of nature. The destruction of the forests around the sources and along the valleys of the rivers by man gave them a more torrential character. The felling of the trees, and the extirpation of the shrubbery upon the fens by domestic cattle, deprived the surface of its cohesion and consistence, and the cutting of peat for fuel opened cavities in it, which, filling at once with water, rapidly extended themselves by abrasion of their borders, and finally enlarged to pools, lakes, and gulfs, like the Lake of Haarlem and the northern part of the Zuiderzee. The cutting of the wood and the depasturing of the grasses upon the sand-dunes converted them from solid bulwarks against the ocean to loose accumulations of dust, which every sea-breeze drove farther landward, burying, perhaps, fertile soil and choking up water-courses on one side, and exposing the coast to erosion by the sea upon the other.

---

* The plan at present most in favor is that which proposes the drainage of only a portion of the southern half of the Zuiderzee, which covers not far from 400,000 acres. The project for the construction of a ship-canal directly from Amsterdam to the North Sea, now in course of execution, embraces the drainage of the Ij, a nearly land-locked basin communicating with the Zuiderzee and covering more than 12,000 acres. See official reports on these projects in *Droogmaking vom het zuidelĳk gedeelte der Zuiderzee, te s' Gravenhage*, 1868, 4to.

Geographical Effect of Physical Improvements in the Netherlands.

The changes which human action has produced within twenty centuries in the Netherlands and the neighboring provinces, are certainly of no small geographical importance, considered simply as a direct question of loss and gain of territory. They have also, as we shall see hereafter, undoubtedly been attended with some climatic consequences, they have exercised a great influence on the spontaneous animal and vegetable life of this region, and they cannot have failed to produce effects upon tidal and other oceanic currents, the range of which may be very extensive. The force of the tidal wave, the height to which it rises, the direction of its currents, and, in fact, all the phenomena which characterize it, as well as all the effects it produces, depend as much upon the configuration of the coast it washes, and the depth of water, and form of bottom near the shore, as upon the attraction which occasions it. Every one of the terrestrial conditions which affect the character of tidal and other marine currents has been very sensibly modified by the operations I have described, and on this coast, at least, man has acted almost as powerfully on the physical geography of the sea as on that of the land.*

Ancient Hydraulic Works.

The hydraulic works of the Netherlands and of the neighboring states are of such magnitude that—with the exception of the dikes of the Mississippi—they quite throw into the shade all other known artificial arrangements for defending the land against the encroachments of the rivers and the sea, and for reclaiming to the domain of agriculture and civilization soil long covered by the waters. But although the recovery and protection of lands flooded by the sea seems to be an art wholly of Netherlandish origin, we have abundant evidence that, in ancient as well as in comparatively modern times, great enterprises more or less analogous in character have been successfully undertaken, both in inland Europe and in the less familiar countries of the East.

In many cases no historical record remains to inform us when or by whom such works were constructed. The Greeks and Romans, the latter especially, were more inclined to undertake and carry out stupendous material enterprises than to boast of them; and many of the grandest and most important constructions of those nations are absolutely unnoticed by contemporary annalists, and are first mentioned by writers living after all knowledge of the epochs of the projectors of these works had perished. Thus the aqueduct known as the Pont du Gard, near Nimes, which, though not surpassing in volume or in probable cost other analogous constructions of ancient and of modern ages, is yet among the most majestic and imposing remains of ancient civil architecture, is not so much as spoken of by any Roman author,* and we are in absolute ignorance of the age or the construction of the remarkable tunnel cut to drain Lake Copais in Bœotia. This lake, now reduced by sedimentary deposit and the growth of aquatic and semi-aquatic vegetation to the condition of a marsh, was originally partially drained by natural subterranean outlets in the underlying limestone rock, many of which still exist. But these emissaries, or *katavothra*, as they are called in both ancient and modern Greek, were insufficient for the discharge of the water, and besides, they were constantly liable to be choked by earth and vegetables, and in such cases the lake rose to a height which produced much injury. To remedy this evil and secure a great accession of fertile soil, at some period anterior to the existence of a written literature in Greece and ages before the time of any prose author whose works have come down to us, two tunnels, one of them four miles long, and of course not inferior to the Torlonian emissary in length, were cut through the solid rock, and may still be followed throughout their whole extent. They were repaired in the time of Alexander the Great, in the fourth century before Christ, and their date was at that time traditionally referred to the reign of rulers who lived as early as the period of the Trojan war.

---

* See, on the influence of the artificial modification of the coast-line on tides and other marine currents, STARING, *De Bodem van Nederland*, i., p. 279.

One of the best known hydraulic works of the Romans is the tunnel which serves to discharge the surplus waters of the Lake of Albano, about fourteen miles from Rome. This lake, about six miles in circuit, occupies one of the craters of an extinct volcanic range, and the surface of its waters is about nine hundred feet above the sea. It is fed by rivulets and subterranean springs originating in the Alban Mount, or Monte Cavo, the most elevated peak of the volcanic group just mentioned, which rises to the height of about three thousand feet. At present the lake has no discoverable natural outlet, and it is not known that the water ever stood at such a height as to flow regularly over the lip of the crater. It seems that at the earliest period of which we have any authentic memorials, its level was usually kept by evaporation, or by discharge through subterranean channels, considerably below the rim of the basin which encompassed it, but in the year 397 B.C., the water, either from the obstruction of such channels, or in consequence of increased supplies from unknown sources, rose to such a height as to flow over the edge of the crater, and threaten inundation to the country below by bursting through its walls. To obviate this danger, a tunnel for carrying off the water was pierced at a level much below the height to which it had risen. This gallery, cut entirely with the chisel through the rock for a distance of six thousand feet, or nearly a mile and one-seventh, is still in so good condition as to serve its original purpose. The fact that this work was contemporaneous with the siege of Veii, has given to ancient annalists occasion to connect the two events, but modern critics are inclined to reject Livy's account of the matter, as one of the many improbable fables which disfigure the pages of that historian. It is, however, repeated by Cicero and by Dionysius of Halicarnassus, and it is by no means impossible that, in an age when priests and soothsayers monopolized both the arts of natural magic and the little which yet existed of physical science, the Government of Rome, by their aid, availed itself at once of the superstition and of the military ardor of its citizens to obtain their sanction to an enterprise which sounder arguments might not have induced them to approve.

---

* One reason for the silence of Roman writers in respect to great material improvements which had no immediate relation to military or political objects, is doubtless the contempt in which mechanical operations and mechanical contrivances were held by that nation of spoilers. Even the engineer, upon whose skill the attack or defence of a great city depended, was only *præfectus fabrum*, the master-artisan, and had no military rank or command. This prejudice continued to a late period in the Middle Ages, and the chiefs of artillery were equally without grade or title as soldiers.

"The occupations of all artisans," says Cicero, "are base, and the shop can have nothing of the respectable." *De Officiis*, l. i., 42. The position of the surgeon relatively to the physician, in England, is a remnant of the same prejudice, which still survives in full vigor in Italy, with regard to both trade and industry. See p. 6, *ante*.

Still more remarkable is the tunnel cut by the Emperor

Claudius to drain the Lake Fucinus, now Lago di Celano, in the former Neapolitan territory, about fifty miles eastward of Rome. This lake, as far as its history is known, has varied very considerably in its dimensions at different periods, according to the character of the seasons. It lies 2,200 feet above the sea, and has no visible outlet, but was originally either drained by natural subterranean conduits, or kept within certain extreme limits by evaporation. In years of uncommon moisture it spread over the adjacent soil and destroyed the crops; in dry seasons it retreated, and produced epidemic disease by poisonous exhalations from the decay of vegetable and animal matter upon its exposed bed. Julius Cæsar had proposed the construction of a tunnel to lower the bed of the lake and provide a regular discharge for its waters, but the enterprise was not actually undertaken until the reign of Claudius, when—after a temporary failure, from errors in levelling by the engineers, as was pretended at the time, or, as now appears certain, in consequence of frauds by the contractors in the execution of the work—it was at least partially completed. From this imperfect construction, it soon got out of repair, but was restored by Hadrian, and is said to have answered its design for some centuries.* In the barbarism which followed the downfall of the empire, it again fell into decay, and though numerous attempts were made to repair it during the Middle Ages, no tolerable success seems to have attended any of these efforts until the present generation.

Draining of Lake Celano by Prince Torlonia.

Works have been some years in progress and are now substantially completed, at a cost of about six millions of dollars, for restoring, or rather enlarging and rebuilding, this ancient tunnel, upon a scale of grandeur which does infinite honor to the liberality and public spirit of the projectors, and with an ingenuity of design and a constructive skill which reflect the highest credit upon the professional ability of the engineers who have planned the works and directed their execution. The length of the Roman tunnel was 18,634 feet, or rather more than three miles and a half, but as the new emissary is designed to drain the lake to the bottom, it must be continued to the lowest part of the basin. It will consequently have a length of not less than 21,000 feet, and, of course, is among the longest subterranean galleries in Europe. Many curious particulars in the design and execution of the original work have been observed in the course of the restoration, but these cannot here be noticed. The difference between the lowest and highest known levels of the surface of the lake is rather more than forty feet, and the difference between the areas covered by water at these levels is not less than nine thousand acres. The complete drainage of the lake, including the ground occasionally flooded, will recover, for agricultural occupation, and permanently secure from inundation, about forty-two thousand acres of as fertile soil as any in Italy.* The ground already dry enough for cultivation furnishes occupation and a livelihood for a population of 16,000 persons, and it is thought that this num-

---

* The fact alluded to in a note on p. 97, *ante*, that since the opening of a communication between Lake Celano and the Garigliano by the works noticed in the text, fish, of species common in the lake, but not previously found in the river, have become naturalized in the Garigliano, is a circumstance of

---

some weight as evidence that the emissary was not actually open in ancient times; for if the waters had been really connected, the fish of the lake would naturally have followed the descending current and established themselves in the river as they have done now.

* Springs rising in the bottom of the lake have materially impeded the process of drainage, and some engineers believe that they will render the complete discharge of the waters impossible. It appears that the earthy and rocky strata underlying the lake are extremely porous, and that the ground already laid dry on the surface absorbs an abnormally large proportion of the precipitation upon it. These strata, therefore, constitute a reservoir which contributes to maintain the springs fed chiefly, no doubt, by underground channels from the neighboring mountains. But it is highly probable that, after a certain time, the process of natural desiccation noticed in note to p. 20, *ante*, will drain this reservoir, and the entire removal of the surface-water will then become practicable.

ber will be augmented to 40,000 when the drainage shall be completely effected.

The new tunnel follows the line of the Claudian emissary—which though badly executed was admirably engineered—but its axis is at a somewhat lower level than that of the old gallery, and its cross-section is about two hundred and fifteen square feet, allowing a discharge of about 2,400 cubic feet to the second, while the Roman work had a cross-section of only one hundred and two square feet, with a possible delivery of 424 cubic feet to the second.

In consequence of the nature of the rock and of the soil, which had been loosened and shattered by the falling in of much of the crown and walls of the old tunnel—every stone of which it was necessary to remove in the progress of the work—and the great head of water in the lake from unusually wet seasons, the technical difficulties to be surmounted were most baffling and discouraging in character, and of such extreme gravity that it may well be doubted whether the art of engineering has anywhere triumphed over more serious obstacles. This great "victory of peace"—probably the grandest work of physical improvement ever effected by the means, the energy, and the munificence of a single individual—is of no small geographical and economical, as well as sanitary, importance, but it has a still higher moral value as an almost unique example of the exercise of public spirit, courage, and perseverance in the accomplishment of a noble and beneficent enterprise by a private citizen.*

The crater-lake of Nemi, in the same volcanic region as that of Albano, is also drained by a subterranean tunnel probably of a temporary pause; but if the outlets are lowered so as to drain the reservoirs, the torrents continue their rapid flow through the ancient bed of the basins, and carry down with them the sand and gravel with which they are charged, instead of depositing their burden as before in the still waters of the lakes.

---

* The draining of Lake Celano was undertaken by a company, but Prince Alessandro Torlonia of Rome bought up the interest of all the shareholders and has executed the entire work at his own private expense. Montricher, the celebrated constructor of the great aqueduct of Marseilles, was the engineer who designed and partly carried out the plans, and after his lamentable death the work has been directed with equal ability by Bermont and Brisse. —See Leon de Rotrou, *Prosciugamento del Lago Fucino*, 8vo. Firenze. 1871.

It is a common opinion in America that the river meadows, bottoms, or *intervales*, as they are popularly called, are generally the beds of ancient lakes which have burst their barriers and left running currents in their place. It was shown by Dr. Dwight, many years ago, that this is very far from being universally true; but there is no doubt that mountain lakes were of much more frequent occurrence in primitive than in modern geography, and there are many chains of such still existing in regions where man has yet little disturbed the original features of the earth. In the long valleys of the Adirondack range in Northern New York, and in the mountainous parts of Maine, eight, ten, and even more lakes and lakelets are sometimes found in succession, each emptying into the next lower pool, and so all at last into some considerable river. When the mountain slopes which supply these basins shall be stripped of their woods, the augmented swelling of the lakes will break down their barriers, their waters will run off, and the valleys will present successions of flats with rivers running through them, instead of chains of lakes connected by natural canals.

A similar state of things seems to have existed in the ancient geography of France. "Nature," says Lavergne, "has not excavated on the flanks of our Alps reservoirs as magnificent as

---

ducted into the canals of irrigation, becomes a source of great fertility."—*La Proprietà Fondiaria*, etc., p. 144.

The quantity of water escaping from the lakes by infiltration depends much on the hydrostatic pressure on the bottom and the walls of the lake-basins, and consequently the depression of the lake surface, diminishing this pressure, would diminish the infiltration. Hence it is possible that the lowering of the level of these lakes would manifest itself in a decreased supply of water for the springs, fontanili, and wells of Lombardy.

those of Lombardy; she had, however, constructed smaller but more numerous lakes, which the improvidence of man has permitted to disappear. Auguste de Gasparin demonstrated more than thirty years ago that many natural dikes formerly existed in the mountain valleys, which have been swept away by the waters."*

Many Alpine valleys in Switzerland and Italy present unquestionable evidence of the former existence of chains of lakes in their basins, and this may be regarded as a general fact in regard to the primitive topography of mountainous regions. Where the forests have not been destroyed, the lakes remain as characteristic features of the geographical surface. But when the woods are felled, these reservoirs are sooner or later filled up by wash from the shores, and of course disappear. Geologists have calculated the period when the bottom of the Lake of Geneva will be levelled up and its outlet worn down. The Rhone will then flow, in an unbroken current, from its source in the great Rhone glacier to the Mediterranean Sea.

Draining of Swamps.

The reclamation of bogs and swamps by draining off the surface-water is doubtless much more ancient than the draining of lakes. The beneficial results of the former mode of improvement are more unequivocal, and balanced by fewer disadvantages, and, at the same time, the processes by which it is effected are much simpler and more obvious. It has accordingly been practised through the whole historical period, and in recent times operations for this purpose have assumed a magnitude, and been attended with economical as well as sanitary and geographical effects, which entitle them to a high place in the efforts of man to ameliorate the natural conditions of the soil he occupies.

The methods by which the draining of marshes is ordinarily accomplished are too familiar, and examples of their successful employment too frequent, to require description, and I shall content myself, for the moment, with a brief notice of some recent operations of this sort which are less generally known than their importance merits.

---

* *Économie Rurale de la France*, p. 289.

Within the present century more than half a million acres of swamp-land have been drained and brought under cultivation in Hungary, and works are in progress which will ultimately recover a still larger area for human use. The most remarkable feature of these operations, and at the same time the process which has been most immediately successful and remunerative, is what is called in Europe the *regulation* of water-courses, and especially of the River Theiss, on the lower course of which stream alone not less than 250,000 acres of pestilential and wholly unproductive marsh have been converted into a healthful region of the most exuberant fertility.

The regulation of a river consists in straightening its channel by cutting off bends, securing its banks from erosion by floods, and, where necessary, by constructing embankments to confine the waters and prevent them from overflowing and stagnating upon the low grounds which skirt their current. In the course of the Theiss about sixty bends, including some of considerable length, have been cut off, and dikes sufficient for securing the land along its banks against inundation have been constructed.

Many thousand acres of land have been recently permanently improved in Italy by the draining of swamps, and extensive operations have been projected and commenced on the lower Rhone, and elsewhere in France, with the same object.*

---

* Very interesting and important experiments, on the practicability of washing out the salt from seacoast lands too highly impregnated with that mineral to be fit for cultivation, are now in progress near the mouth of the Rhone, where millions of acres of marshy soil can easily be recovered, if these experiments are successful.

See Duponchel, *Traité d'Hydraulique et de Géologie agricoles.* Paris, 1868, chap. xi. and xii.

In the neighborhood of Ferrara are pools and marshes covering nearly two hundred square miles, or a surface more than equal to eight American townships. Centrifugal steam-pumps, of 2,000 horse-power, capable of discharging more than six hundred and fifty millions of gallons of water per day, have

But there is probably no country where greater improvements of this sort have either been lately effected, or are now in course of accomplishment, than in our own. Not to speak of well-known works on the New Jersey seacoast and the shores of Lake Michigan, the people of the new State of California are engaging in this mode of subduing nature with as much enterprise and energy as they have shown in the search for gold. The Report of the Agricultural Department of the United States for January, 1872, notices, with more or less detail, several highly successful experiments in California in the way of swamp-drainage and securing land from overflow, and it appears that not far from 200,000 acres have either very recently undergone or will soon be subjected to this method of improvement.

Agricultural Draining.

I have commenced this chapter with a description of the dikes and other hydraulic works of the Netherland engineers, because both the immediate and the remote results of such operations are more obvious and more easily measured, though certainly not more important, than those of much older and more widely diffused modes of resisting or directing the flow of waters, which have been practised from remote antiquity in the interior of all civilized countries. Draining and irrigation are habitually regarded as purely agricultural processes, having little or no relation to technical geography; but we shall find that they exert a powerful influence on soil, climate, and animal and vegetable life, and may, therefore, justly claim to be regarded as geographical elements.

Superficial draining is a necessity in all lands newly reclaimed from the forest. The face of the ground in the woods is never so regularly inclined as to permit water to flow freely

---

lately been constructed in England for draining these marshes. This discharge is equal to an area of 640 acres, or a mile square, with nearly three feet of water.

over it. There are, even on the hillsides, small ridges and depressions, partly belonging to the original distribution of the soil, and partly occasioned by irregularities in the growth and deposit of vegetable matter. These, in the husbandry of nature, serve as dams and reservoirs to collect a larger supply of moisture than the spongy earth can at once imbibe. Besides this, the vegetable mould is, even under the most favorable circumstances, slow in parting with the humidity it has accumulated under the protection of the woods, and the infiltration from neighboring forests contributes to keep the soil of small clearings too wet for the advantageous cultivation of artificial crops. For these reasons, surface draining must have commenced with agriculture itself, and there is probably no cultivated district, one may almost say no single field, which is not provided with artificial arrangements for facilitating the escape of superficial water, and thus carrying off moisture which, in the natural condition of the earth, would have been imbibed by the soil.

All these processes belong to the incipient civilization of the ante-historical periods, but the construction of subterranean channels for the removal of infiltrated water marks ages and countries distinguished by a great advance in agricultural theory and practice, a great accumulation of pecuniary capital, and a density of population which creates a ready demand and a high price for all products of rural industry. Under-draining, too, would be most advantageous in damp and cool climates, where evaporation is slow, and upon soils where the natural inclination of surface does not promote a very rapid flow of the surface-waters. All the conditions required to make this mode of rural improvement, if not absolutely necessary, at least profitable, exist in Great Britain, and it is, therefore, very natural that the wealthy and intelligent farmers of England should have carried this practice farther, and reaped a more abundant pecuniary return from it, than those of any other country.

Besides superficial and subsoil drains, there is another method of disposing of superfluous surface-water, which, however, can rarely be practised, because the necessary conditions for its employment are not of frequent occurrence. Whenever a tenacious water-holding stratum rests on a loose, gravelly bed, so situated as to admit of a free discharge of water from or through it by means of the outcropping of the bed at a lower level, or of deep-lying conduits leading to distant points of discharge, superficial waters may be carried off by opening a passage for them through the impervious into the permeable stratum. Thus, according to Bischof, as early as the time of King Réné, in the first half of the fifteenth century, when subsoil drainage was scarcely known, the plain of Paluns, near Marseilles, was laid dry by boring, and Wittwer informs us that drainage is effected at Munich by conducting the superfluous water into large excavations, from which it filters through into a lower stratum of pebble and gravel lying a little above the level of the river Isar.* So at Washington, in the western part of the city, which lies high above the rivers Potomac and Rock Creek, many houses are provided with dry wells for draining their cellars and foundations. These extend through hard, tenacious earth to the depth of thirty or forty feet, when they strike a stratum of gravel, through which the water readily passes off.

---

* *Physikalische Geographie*, p. 288. This method is now frequently employed in France. Details as to the processes will be found in MANGON, *Pratique du Drainage*, pp. 78 *et seqq*. Draining by driving down stakes, mentioned in a note in the chapter on the Woods, *ante*, is a process of the same nature.

In the United States, large tracts of marshy ground, and even shallow lakes of considerable extent, have been sufficiently drained not only for pasturage but for cultivation, without resort to any special measures for effecting that end. The ordinary processes of rural improvement in the vicinity, such as felling woods upon and around such grounds, and the construction of roads, the side ditches of which act as drains, over or near them, aided now and then by the removal of a fallen tree or other accidental obstruction in the beds of small streams which flow from them, often suffice to reclaim miles square of unproductive swamp and water. See notes on p. 20, and on cedar swamps, p. 208, *ante*.

This practice has been extensively employed at Paris, not merely for carrying off ordinary surface-water, but for the discharge of offensive and deleterious fluids from chemical and manufacturing establishments. A well of this sort received, in the winter of 1832–'33, twenty thousand gallons per day of the foul water from a starch factory, and the same process was largely used in other factories. The apprehension of injury to common and artesian wells and springs led to an investigation on this subject by Girard and Parent Duchatelet, in the latter year. The report of these gentlemen, published in the *Annales des Ponts et Chaussées* for 1833, second half-year, is full of curious and instructive facts respecting the position and distribution of the subterranean waters under and near Paris; but it must suffice to say that the report came to the conclusion that, in consequence of the absolute immobility of these waters, and the relatively small quantity of noxious fluid to be conveyed to them, there was no danger of the diffusion of such fluid if discharged into them. This result will not surprise those who know that, in another work, Duchatelet maintains analogous opinions as to the effect of the discharge of the city sewers into the Seine or the waters of that river. The quantity of matter delivered by them he holds to be so nearly infinitesimal, as compared with the volume of water of the river, that it cannot possibly affect it to a sensible degree, and therefore cannot render the Seine water unfit for drinking.*

Meteorological Effects of Draining.

The draining of lakes diminishes the water-surface of the soil, and consequently, in many cases, the evaporation from it, as well as the refrigeration which attends all evaporation.* On the other hand, if the volume of water abstracted is great, its removal deprives its basin of an equalizing and moderating influence; for large bodies of water take very slowly the temperature of the air in contact with their surface, and are almost constantly either sending off heat into the atmosphere or absorbing heat from it. Besides, as we have seen, lakes in elevated positions discharge more or less water by infiltration, and contribute it by the same process to other lakes, to springs, and to rivulets, at lower levels. Hence the draining of lakes, on a considerable scale, must modify both the humidity and the temperature of the atmosphere of the neighboring regions, and the permanent supply of ground-water for the lands lying below them.

---

* Coste found, in his experiments on pisciculture, that the fermentation, which takes place in the water of the Seine in consequence of the discharge of the drains into the river, destroyed a large proportion of the eggs of fish in his breeding basins. Analysis of Seine water by Boussingault in 1855 detected a considerable quantity or ammonia.

Meteorological Action of Marshes.

The shallow water of marshes, indeed, performs this latter function, but, under ordinary circumstances, marshes exercise in but a very small degree the compensating meteorological action which I have ascribed to large expansions of deeper water. The direct rays of the sun and the warmth of the atmosphere penetrate to the soil beneath, and raise the temperature of the water which covers it; and there is usually a much greater evaporation from marshes than from lakes in the same region, during the warmer half of the year. This evaporation implies refrigeration, and consequently the diminution of evaporation by the drainage of swamps tends to prevent the lowering of the atmospheric temperature, and to lessen the frequency and severity of frosts. Accordingly it is a fact of experience that, other things being equal, dry soils, and the air in contact with them, are perceptibly warmer during the season of vegetation, when evaporation is most rapid, than moist lands and the atmospheric stratum resting upon them. Instrumental observation on this special point has not yet been undertaken on a large scale, but still we have thermometric data sufficient to warrant the general conclusion, and the influence of drainage in diminishing the frequency of frost appears to be even better established than a direct increase of atmospheric temperature. The steep and dry uplands of the Green Mountain range in New England often escape frosts when the Indian-corn harvest on moister grounds, five hundred or even a thousand feet lower, is destroyed or greatly injured by them. The neighborhood of a marsh is sure to be exposed to late spring and early autumnal frosts, but they cease to be feared after it is drained, and this is particularly observable in very cold climates, as, for example, in Lapland.*

---

* The relative evaporating action of earth and water is a very complicated problem, and the results of observation on the subject are conflicting. Schübler found that at Geneva the evaporation from bare loose earth, in the months of December, January, and February, was from two and a half to nearly six times as great as from a like surface of water in the other months. The evaporation from water was from about once and a half to six times as great as from earth. Taking the whole year together, the evaporation from the two surfaces was $199\frac{8}{12}$ lines from earth and $536\frac{1}{12}$ lines from water. Experiments by Van der Steer, at the Helder, in the years 1861 and 1862, showed, for the former year, an evaporation of 602.9 millimètres from water, 1399.6 millimètres from ground covered with clover and other grasses; in 1862, the evaporation from water was 584.5 millimètres, from grass-ground, 875.5.—WILHELM, *Der Boden und das Wasser*, p. 57; KRECKE, *Het Klimaat van Nederland*, ii., p. 111.

On the other hand, the evaporation from the Nile in Egypt and Nubia is stated to be three times as great as that from an equal surface of the soil which borders it.—LOMBARDINI, *Saggio Idrologico sul Nilo*, Milano, 1864, and *Appendix*. The relative thermometrical conditions of land and water in the same vicinity are constantly varying, and the hygrometrical state of both is equally unstable. Consequently there is no general formula to express the proportionate evaporation from fluid and solid geographical surfaces.

In England, under-drains are not generally laid below the reach of daily variations of temperature, or below a point from which moisture, if not carried off by the drains, might be brought to the surface by capillary attraction, and evaporated by the heat of the sun. They, therefore, like surface-drains, withdraw from local solar action much moisture which would otherwise be vaporized by it, and, at the same time, by drying the soil above them, they increase its effective hygroscopicity, and it consequently absorbs from the atmosphere a greater quantity of water than it did when, for want of under-drainage, the subsoil was always humid, if not saturated.* Under-drains, then, contribute to the dryness as well as to the warmth of the atmosphere, and, as dry ground is more readily heated by the rays of the sun than wet, they tend also to raise the mean, and especially the summer, temperature of the soil.

---

* "The simplest backwoodsman knows by experience that all cultivation is impossible in the neighborhood of bogs and marshes. Why is a crop near the borders of a marsh cut off by frost, while a field upon a hillock, a few stone's throws from it, is spared?"—LARS LEVI LÆSTADIUS, *Om Uppodlingar i Lappmarken*, pp. 69, 74.

Effects of Draining Lake of Haarlem.

The meteorological influence of the draining of lakes and of humid soils has not, so far as I know, received much attention from experimental physicists; but we are not altogether without direct proof in support of theoretical and *a priori* conclusions. Thermometrical observations have been regularly made at Zwanenburg, near the northern extremity of the Lake of Haarlem, for more than a century; and since 1845 a similar registry has been kept at the Helder, forty or fifty miles more to the north. In comparing these two series of observations, it is found that towards the end of 1852, when the draining of the lake was finished, and the following summer had completely dried the newly exposed soil—and, of course, greatly diminished the water-surface—a change took place in the relative temperature of those two stations. Taking the mean of each successive period of five days, from 1845 to 1852, both inclusive, the temperature of Zwanenburg was thirty-three hundredths of a degree centigrade *lower* than at the Helder. From the end of 1852 the thermometer at Zwanenburg has stood, from the 11th of April to the 20th of September, twenty-two hundredths of a degree *higher* than that at Helder; but from the 14th of October to the 17th of March, it has marked one-tenth of a degree *lower* than its mean between the same dates before 1853.*

---

* Mangon thinks that the diminution of evaporation by agricultural drainage corresponds, in certain circumstances, to five per cent. of the heat received from the sun by the same surface in a year. He cites observations by Parkes, showing a difference in temperature of 5.5° [centigrade ?] in favor of drained, as compared with undrained, ground in the same vicinity.—*Instructions pratiques sur le Drainage*, pp. 227, 228.

The diminution of evaporation is not the only mode in which under-draining affects the temperature. The increased effective hygroscopicity of the soil increases its absorbent action, and the condensation of atmospheric vapor thus produced is attended with the manifestation of heat.

There is no reason to doubt that these differences are due to the draining of the lake. In summer, solar irradiation has acted more powerfully on the now exposed earth and of course on the air in contact with it; and there is no longer a large expanse of water still retaining and of course imparting something of the winter temperature; in winter, the earth has lost more heat by radiation than when covered by water, and the influence of the lake, as a reservoir of warmth accumulated in summer and gradually given out in winter, was of course lost by its drainage. Doubtless the quantity of moisture contained in the atmosphere has been modified by the same cause, but it does not appear that observations have been made upon this point. Facts lately observed by Glaisher tend to prove an elevation of not far from two degrees in the mean temperature of England during the course of the last hundred years. For reasons which I have explained elsewhere, the early observations upon which these conclusions are founded do not deserve entire confidence; but admitting the fact of the alleged elevation, its most probable explanation would be found in the more thorough draining of the soil by superficial and by subterranean conduits.

So far as respects the immediate improvement of soil and climate, and the increased abundance of the harvests, the English system of surface and subsoil drainage has fully justified the eulogiums of its advocates; but its extensive adoption appears to have been attended with some altogether unforeseen and undesirable consequences, very analogous to those which I have described as resulting from the clearing of the forests. The under-drains carry off very rapidly the water imbibed by the soil from precipitation, and through infiltration from neighboring springs or other sources of supply. Consequently, in wet seasons, or after heavy rains, a river bordered by artificially drained lands receives in a few hours, from superficial and from subterranean conduits, an accession of water which, in the natural state of the earth, would have reached it only by small instalments after percolating through hidden paths for weeks or even months, and would have furnished perennial and comparatively regular contributions, instead of swelling deluges, to its channel. Thus, when human impatience rashly substitutes swiftly acting artificial contrivances for the slow methods by which nature drains the surface and superficial strata of a river-basin, the original equilibrium is disturbed, the waters of the heavens are no longer stored up in the earth to be gradually given out again, but are hurried out of man's domain with wasteful haste; and while the inundations of the river are sudden and disastrous, its current, when the drains have run dry, is reduced to a rivulet, it ceases to supply the power to drive the machinery for which it was once amply sufficient, and scarcely even waters the herds that pasture upon its margin.

---

* KRECKE, *Het Klimaat van Nederland*, ii., p. 64.

The water of subterranean currents and reservoirs, as well as that of springs and common wells, is doubtless principally furnished by infiltration, and hence its quantity must vary with every change of natural surface which tends to accelerate or to retard the drainage of the surface-soil. The drainage of marshes, therefore, and all other methods of drying the superficial strata, whether by open ditches or by underground tubes or drains, has the same effect as clearing off the forest in depriving the subterranean waters of accessions which they would otherwise receive by infiltration, and in proportion as the sphere of such operation is extended, their influence will make itself felt in the diminished supply of water in springs and wells.*

Geographical and Meteorological Effects of Aqueducts, Reservoirs, and Canals.

Many of the great processes of internal improvement, such as aqueducts for the supply of great cities, railroad cuts and embankments, and the like, divert water from its natural channels, and affect its distribution and ultimate discharge. The collecting of the waters of a considerable district into reservoirs, to be thence carried off by means of aqueducts, as, for example, in the forest of Belgrade, near Constantinople, deprives the grounds originally watered by the springs and rivulets of the necessary moisture, and reduces them to barrenness.† Similar effects must have followed from the construction of the numerous aqueducts which supplied ancient Rome with such a profuse abundance of water.* On the other hand, the filtration of water through the banks or walls of an aqueduct carried upon a high level across low ground, often injures the adjacent soil, and is prejudicial to the health of the neighboring population; and it has been observed in Switzerland and elsewhere, that fevers have been produced by the stagnation of the water in excavations from which earth had been taken to form embankments for railways.

---

* Babinet condemns the general draining of marshes. "Draining," says he, "has been much in vogue for some years, and it has been a special object to dry and fertilize marshy grounds. I believe that excessive dryness is thus produced, and that other soils in the neighborhood are sterilized in proportion."—*Études et Lectures*, iv., p. 118.

"The extent of soil artificially dried by drainage is constantly increasing, and the water received by the surface from precipitation flows off by new channels, and is in general carried off more rapidly than before. Must not this fact exercise an influence on the régime of springs whose basin of supply thus undergoes a more or less complete transformation?"—BERNHARD COTTA, *Preface to* PARAMELLE, *Quellenkunde*, p. vii., viii.

The effects of agricultural drainage are perceptible at great depths. It has been observed in Cornwall that deep mines are more free from water in well-drained districts than in those where drainage is not generally practised.—ESQUIROS, *Revue des Deux Mondes*, 15 Nov., 1863, p. 430.

See also ASBJÖRNSEN, *Torv og Torvdrift*, p. 31.

† See a very interesting paper on the *Water-Supply of Constantinople*, by Mr. Homes, of the New York State Library, in the *Albany Argus* of June 6, 1872. The system of aqueducts for the supply of water to that city was commenced by Constantine, and the great aqueduct, frequently ascribed to Justinian, which is 840 feet long and 112 feet high, is believed to have been constructed during the reign of the former emperor.

If we consider only the influence of physical improvements on civilized life, we shall perhaps ascribe to navigable canals a higher importance, or at least a more diversified influence, than to aqueducts or to any other works of man designed to control the waters of the earth, and to affect their distribution. They bind distant regions together by social ties, through the agency of the commerce they promote; they facilitate the transportation of military stores and engines, and of other heavy material connected with the discharge of the functions of government; they encourage industry by giving marketable value to raw material and to objects of artificial elaboration which would otherwise be worthless on account of the cost of conveyance; they supply from their surplus waters means of irrigation and of mechanical power; and, in many other ways, they contribute much to advance the prosperity and civilization of nations. Nor are they wholly without geographical importance. They sometimes drain lands by conveying off water which would otherwise stagnate on the surface, and, on the other hand, like aqueducts, they render the neighboring soil cold and moist by the percolation of water through their embankments; † they dam up, check, and divert the course of natural currents, and deliver them at points opposite to, or distant from, their original outlets; they often require extensive reservoirs to feed them, thus retaining through the year accumulations of water—which would otherwise run off, or evaporate in the dry season—and thereby enlarging the evaporable surface of the country; and we have already seen that they interchange the flora and the fauna of provinces widely separated by nature. All these modes of action certainly influence climate and the character of terrestrial surface, though our means of observation are not yet perfected enough to enable us to appreciate and measure their effects.

---

* The unhealthiness of the Roman Campagna is ascribed by many mediæval as well as later writers to the escape of water from the ancient aqueducts, which had fallen out of repair from neglect, or been broken down by enemies in the sieges of Rome.

† Sismondi, speaking of the Tuscan canals, observes: "But inundations are not the only damage caused by the waters to the plains of Tuscany. Raised, as the canals are, above the soil, the water percolates through their banks, penetrates every obstruction, and, in spite of all the efforts of industry, sterilizes and turns to morasses fields which nature and the

Antiquity of Irrigation.

We know little of the history of the extinct civilizations which preceded the culture of the classic ages, and no nation has, in modern times, spontaneously emerged from barbarism, and created for itself the arts of social life.* The improve-

---

richness of the soil seemed to have designed for the most abundant harvests. In ground thus pervaded with moisture, or rendered *cold*, as the Tuscans express it, by the filtration of the canal-water, the vines and the mulberries, after having for a few years yielded fruit of a saltish taste, rot and perish. The wheat decays in the ground, or dies as soon as it sprouts. Winter crops are given up, and summer cultivation tried for a time; but the increasing humidity, and the saline matter communicated to the earth—which affects the taste of all its products, even to the grasses, which the cattle refuse to touch—at last compel the husbandman to abandon his fields, and leave uncultivated a soil that no longer repays his labor."—*Tableau de l'Agriculture Toscane*, pp. 11, 12.

* I ought perhaps to except the Mexicans and the Peruvians, whose arts and institutions are not yet shown to be historically connected with those of any more ancient people. The lamentable destruction of so many memorials of these tribes, by the ignorance and bigotry of the so-called Christian barbarians who conquered them, has left us much in the dark as to many points of their civilization; but they seem to have reached that stage where continued progress in knowledge and in power over nature is secure, and a few more centuries of independence might have brought them to originate for themselves most of the great inventions which the last four centuries have bestowed upon man.

ments of the savage races whose history we can distinctly trace are borrowed and imitative, and our theories as to the origin and natural development of industrial art are conjectural. Of course, the relative antiquity of particular branches of human industry depends much upon the natural character of soil, climate, and spontaneous vegetable and animal life in different countries; and while the geographical influence of man would, under given circumstances, be exerted in one direction, it would, under different conditions, act in an opposite or a diverging line. I have given some reasons for thinking that in the climates to which our attention has been chiefly directed, man's first interference with the natural arrangement and disposal of the waters was in the way of drainage of surface. But if we are to judge from existing remains alone, we should probably conclude that irrigation is older than drainage; for, in the regions regarded by general tradition as the cradle of the human race, we find traces of canals evidently constructed for the former purpose at a period long preceding the ages of which we have any written memorials. There are, in ancient Armenia, extensive districts which were already abandoned to desolation at the earliest historical epoch, but which, in a yet remoter antiquity, had been irrigated by a complicated and highly artificial system of canals, the lines of which can still be followed; and there are, in all the highlands where the sources of the Euphrates rise, in Persia, in Egypt, in India, and in China, works of this sort which must have been in existence before man had begun to record his own annals.

In warm countries, such as most of those just mentioned, the effects I have described as usually resulting from the clearing of the forests would very soon follow. In such climates, the rains are inclined to be periodical; they are also violent, and for these reasons the soil would be parched in summer and liable to wash in winter. In these countries, therefore, the necessity for irrigation must soon have been felt, and its introduction into mountainous regions like Armenia must have been immediately followed by a system of terracing, or at least scarping the hillsides. Pasture and meadow, indeed, may be irrigated even when the surface is both steep and irregular, as may be observed abundantly on the Swiss as well as on the Piedmontese slope of the Alps; but in dry climates, ploughland and gardens on hilly grounds require terracing, both for supporting the soil and for administering water by irrigation, and it should be remembered that terracing, of itself, even without special arrangements for controlling the distribution of water, prevents or at least checks the flow of rain-water, and gives it time to sink into the ground instead of running off over the surface.

The summers in Egypt, in Syria, and in Asia Minor and even Rumelia, are almost rainless. In such climates, the necessity of irrigation is obvious, and the loss of the ancient means of furnishing it helps to explain the diminished fertility of most of the countries in question.* The surface of Palestine, for example, is composed, in a great measure, of rounded limestone hills, once, no doubt, covered with forests. These were partially removed before the Jewish conquest.† When the soil began to suffer from drought, reservoirs to retain the waters of winter were hewn in the rock near the tops of the hills, and the declivities were terraced. So long as the cisterns were in good order, and the terraces kept up, the fertility of Palestine was unsurpassed, but when misgovernment and foreign and intestine war occasioned the neglect or destruction of these works—traces of which still meet the traveller's eye at every step,—when the reservoirs were broken and the terrace walls had fallen down, there was no longer water for irrigation in summer, the rains of winter soon washed away most of the thin layer of earth upon the rocks, and Palestine was reduced almost to the condition of a desert.

---

* In Egypt, evaporation and absorption by the earth are so rapid, that all annual crops require irrigation during the whole period of their growth. As fast as the water retires by the subsidence of the annual inundation, the seed is sown upon the still moist, uncovered soil, and irrigation begins at once. Upon the Nile, you hear the creaking of the water-wheels, and sometimes the movement of steam-pumps, through the whole night, while the poorer cultivators unceasingly ply the simple *shadoof*, or bucket-and-sweep, laboriously raising the water from trough to trough by as many as six or seven stages when the river is low. The bucket is of flexible leather, with a stiff rim, and is emptied into the trough, not by inverting it like a wooden bucket, but by putting the hand beneath and pushing the bottom up till the water all runs out over the brim, or, in other words, by turning the vessel inside out.

The quantity of water thus withdrawn from the Nile is enormous. Most of this is evaporated directly from the surface or the superficial strata, but some moisture percolates down and oozes through the banks into the river again, while a larger quantity sinks till it joins the slow current of infiltration by which the Nile water pervades the earth of the valley to the distance, at some points, of not less than fifty miles.

† "Forests," "woods," and "groves," are frequently mentioned in the Old Testament as existing at particular places, and they are often referred to by way of illustration, as familiar objects. "Wood" is twice spoken of as a material in the New Testament, but otherwise—at least according to Cruden—

The course of events has been the same in Idumæa. The observing traveller discovers everywhere about Petra, particularly if he enters the city by the route of Wadi Ksheibeh, very extensive traces of ancient cultivation, and upon the neighboring ridges are the ruins of numerous cisterns evidently constructed to furnish a supply of water for irrigation.* In primitive ages, the precipitation of winter in these hilly countries was, in great part, retained for a time in the superficial soil, first by the vegetable mould of the forests, and then by the artificial arrangements I have described. The water imbibed by the earth was partly taken up by direct evaporation, partly absorbed by vegetation, and partly carried down by infiltration to subjacent strata

---

not one of the above words occurs in that volume. In like manner, while the box, the cedar, the fir, the oak, the pine, "beams," and "timber," are very frequently mentioned in the Old Testament, not one of these words is found in the New, *except* the case of the "beam in the eye," in the parable in Matthew and Luke.

This interesting fact, were other evidence wanting, would go far to prove that a great change had taken place in this respect between the periods when the Old Testament and the New were respectively composed; for the scriptural writers, and the speakers introduced into their narratives, are remarkable for their frequent allusions to the natural objects and the social and industrial habits which characterized their ages and their country.

* One of these on Mount Hor, two stories deep, is in such good preservation, although probably not repaired for many centuries, that I found ten feet of water in it in June, 1851.

which gave it out in springs at lower levels, and thus a fertility of soil and a condition of the atmosphere were maintained sufficient to admit of the dense population that once inhabited those now arid wastes. At present, the rain-water runs immediately off from the surface and is carried down to the sea, or is drunk up by the sands of the wadis, and the hillsides which once teemed with plenty are bare of vegetation, and seared by the scorching winds of the desert.

In fact, climatic conditions render irrigation a necessity in all the oriental countries which have any importance in ancient or in modern history, and there can be no doubt that this diffusion of water over large surfaces has a certain reaction on climate. Some idea of the extent of artificially watered soil in India many be formed from the fact that in fourteen districts of the Presidency of Madras, not less than 43,000 reservoirs, constructed by the ancient native rulers for the purpose of irrigation, are now in use, and that there are in those districts at least 10,000 more which are in ruins and useless. These reservoirs are generally formed by damming the outlets of natural valleys; and the dams average half a mile in length, though some of them are thirty miles long and form ponds covering from 37,000 to 50,000 acres. The areas of these reservoirs alone considerably increase the water-surface, and each one of them irrigates an extent of cultivated ground much larger than itself. Hence there is a great augmentation of humid surface from these constructions.[*]

---

[*] The present government of India obtains the same result more economically and advantageously by constructing in many provinces of that vast empire canals of great length and capacity, which not only furnish a greater supply of water than the old reservoirs, but so distribute it as to irrigate a larger area than could be watered by any system of artificial basins. The excavations for the Ganges Canal were nearly equal to those for the Suez Canal, falling little short of 100,000 cubic yards, without counting feeders and accessory lines amounting to a length of 3,000 miles. This canal, according to a recent article in the *London Times*, waters a tract of land 320 miles long by 50 broad. The Jumna Canal, 130 miles long, with 608 miles of distributing branches, waters a territory 120 miles long with a breadth of 15 miles.

Other statements estimate the amount of land actually under irrigation in

The cultivable area of Egypt, or the space between desert and desert where cultivation would be possible, is now estimated at ten thousand square statute miles.[*] Much of the surface, though not out of the reach of irrigation, lies too high to be economically watered, and irrigation and cultivation are therefore at present confined to an area of seven thousand square miles, nearly the whole of which is regularly and constantly watered when not covered by the inundation, except in the short interval between the harvest and the rise of the waters. For nearly half of the year, then, irrigation adds seven thousand square miles to the humid surface of the Nile valley, or, in other words, more than decuples the area from which an appreciable quantity of moisture would otherwise be evaporated; for after the Nile has retired within its banks, its waters by no means cover one-tenth of the space just mentioned.

The Nile receives not a single tributary in its course below Khartoum; there is not so much as one living spring in the

---

British India at 6,000,000 acres, and add that canals now in construction will water as much more. The Indian irrigation canals are generally navigable, some of them by boats of large tonnage, and the canals return a net revenue of from five to twenty per cent. on their cost.

[*] The area which the waters of the Nile, left to themselves, would now cover is greater than it would have been in ancient times, because the bed of the river has been elevated, and consequently the lateral spread of the inundation increased. See SMITH'S *Dictionary of Geography*, article "Ægyptus." But the industry of the Egyptians in the days of the Pharaohs and the Ptolemies carried the Nile-water to large provinces, which have now been long abandoned and have relapsed into the condition of desert. "Anciently," observes the writer of the article "Egypt" in Smith's *Dictionary of the Bible*, "2,735 square miles more [about 3,700 square statute miles] may have been cultivated. In the best days of Egypt, probably all the land was cultivated that could be made available for agricultural purposes, and hence we may estimate the ancient arable area of that country at not less than 11,000 square statute miles, or fully double its present extent."

According to an article in the *Bollettino della Società Geografica Italiana*, vol. v., pt. iii., p. 219, the cultivated soil of Egypt in 1869 amounted to 4,500,000 acres, and the remaining soil capable of cultivation was estimated at 2,000,000 acres.

whole land,* and, with the exception of a narrow strip of coast, where the annual precipitation is said to amount to six inches, the fall of rain in the territory of the Pharaohs is not two inches in the year. The subsoil of the whole valley is pervaded with moisture by infiltration from the Nile, and water can everywhere be found at the depth of a few feet. Were irrigation suspended, and Egypt abandoned, as in that case it must be, to the operations of nature, there is no doubt that trees, the roots of which penetrate deeply, would in time establish themselves on the deserted soil, fill the valley with verdure, and perhaps at last temper the climate, and even call down abundant rain from the heavens.† But the immediate effect of discontinuing irrigation would be, first, an immense reduction of the evaporation from the valley in the dry season, and then a greatly augmented dryness and heat of the atmosphere. Even the almost constant north wind—the strength of which would be increased in consequence of these changes—would little reduce the temperature of the narrow cleft between the burning mountains which hem in the channel of the Nile, so that a single year would transform the most fertile of soils to the most barren of deserts, and render uninhabitable a territory that irrigation makes capable of sustaining as dense a population as has ever existed in any part of the world.‡ Whether man found the valley of the Nile a forest, or such a waste as I have just described, we do not historically know. In either case, he has not simply converted a wilderness into a garden, but has unquestionably produced extensive climatic change.*

---

* The so-called spring at Heliopolis is only a thread of water infiltrated from the Nile or the canals.

† The date and the doum palm, the *sont* and many other acacias, the caroub, the sycamore and other trees grow in Egypt without irrigation, and would doubtless spread through the entire valley in a few years.

‡ Wilkinson states that the total population, which, two hundred years ago, was estimated at 4,000,000, amounted till lately to only about 1,800,000 souls, having been reduced since the year 1800 from 2,500,000 to less than 2,000,000. —*Handbook for Travellers in Egypt*, p. 10. The population at the end of the year 1869 is computed at 5,215,000.—*Bollettino della Soc. Geog. Ital.*, vol. v., pt. iii., p. 215. This estimate doubtless includes countries bordering on the upper Nile not embraced in Wilkinson's statistics.

The fields of Egypt are more regularly watered than those of any other country bordering on the Mediterranean, except the rice-grounds in Italy, and perhaps the *marcite* or winter meadows of Lombardy; but irrigation is more or less employed throughout almost the entire basin of that sea, and is everywhere attended with effects which, if less in degree, are analogous in character, to those resulting from it in Egypt.

---

* Ritter supposes Egypt to have been a sandy desert when it was first occupied by man. "The first inhabitant of the sandy valley of the Nile was a desert-dweller, as his neighbors right and left, the Libyan, the nomade Arab, still are. But the civilized people of Egypt transformed, by canals, the waste into the richest granary of the world; they liberated themselves from the shackles of the rock and sand desert, in the midst of which, by a wise distribution of the fluid through the solid geographical form, by irrigation in short, they created a region of culture most rich in historical monuments."—*Einleitung zur allgemeinen vergleichenden Geographie*, pp. 165, 166.

This view seems to me highly improbable; for great rivers, in warm climates, are never bordered by sandy plains. A small stream may be swallowed up by sands, but if the volume of water is too large to be carried off by evaporation or drank up by absorption, it saturates its banks with moisture, and unless resisted by art, converts them into marshes covered with aquatic vegetation. By canals and embankments, man has done much to modify the natural distribution of the waters of the Nile; yet the annual inundation is not his work, and the river must have overflowed its banks and carried spontaneous vegetation with its waters, as well before as since Egypt was first occupied by the human family. There is, indeed, some reason to suppose that man lived upon the banks of the Nile when its channel was much lower, and the spread of its inundations much narrower, than at present; but wherever its flood reached, there the forest would propagate itself, and its shores would certainly have been morasses rather than sands.

The opinions of Ritter on this subject are not only improbable, but they are contradictory to the little historical testimony we possess. Herodotus informs us in *Euterpe* that except the province of Thebes, all Egypt, that is to say, the whole of the Delta and of middle Egypt extending to Hemopolis Magna in N. L. 27° 45′, was originally a morass. This morass was doubtless in great part covered with trees, and hence, in the most ancient hieroglyphical records, a tree is the sign for the cultivated land between the desert and the channel of the Nile. In all probability, the real change effected by human art in the superficial geography of Egypt, is the conversion of pools and marshes into dry land, by a system of transverse dikes, which compelled the flood-water to deposit its sediment on the banks of the river instead of carrying it to the sea. The *colmate* of modern Italy were thus anticipated in ancient Egypt.

There are few things in European husbandry which surprise English or American observers so much as the extent to which irrigation is employed in agriculture, and that, too, on soils, and with a temperature, where their own experience would have led them to suppose it would be injurious to vegetation rather than beneficial to it. In Switzerland, for example, grass-grounds on the very borders of glaciers are freely irrigated, and on the Italian slope of the Alps water is applied to meadows at heights exceeding 6,000 feet. The summers in Northern Italy, though longer, are very often not warmer than in the Northern United States; and in ordinary years, the summer rains are as frequent and as abundant in the former country as in the latter.* Yet

---

* The mean annual precipitation in Lombardy is thirty-six inches, of which nearly two-thirds fall during the season of irrigation. The rain-fall is about the same in Piedmont, though the number of days in the year classed as "rainy" is said to be but twenty-four in the former province while it is seventy in the latter.—BAIRD SMITH, *Italian Irrigation*, vol. i., p. 196.

The necessity of irrigation in the great alluvial plain of Northern Italy is partly explained by the fact that the superficial stratum of fine earth and vegetable mould is very extensively underlaid by beds of pebbles and gravel brought down by mountain torrents at a remote epoch. The water of the surface-soil drains rapidly down into these loose beds, and passes off by subterranean channels to some unknown point of discharge; but this circumstance alone is not a sufficient solution. Is it not possible that the habits of vegetables, grown in countries where irrigation has been immemorially employed, have been so changed that they require water under conditions of soil and climate where their congeners, which have not been thus indulgently treated, do not? It is a remarkable fact that during the season of irrigation, when large tracts of surface are almost constantly saturated with water, there is an extraordinary dryness in the atmosphere of Lombardy, the hygrometer standing for days together a few degrees only above zero, while in winter the instrument indicates extreme humidity of the air, approaching to total saturation.—BAIRD SMITH, *Italian Irrigation*, i., p. 189.

There are some atmospheric phenomena in Northern Italy, which an American finds it hard to reconcile with what he has observed in the United States. To an American eye, for instance, the sky of Piedmont, Lombardy, and the northern coast of the Mediterranean, is always whitish and curdled, and it never has the intensity and fathomless depth of the blue of his native in Piedmont and Lombardy irrigation is bestowed upon almost every crop, while in our Northern States it is never employed at all in farming husbandry, or indeed for any purpose except in kitchen-gardens, and possibly, in rare cases, in some other small branch of agricultural industry.*

In general, it may be said that irrigation is employed only in the seasons when the evaporating power of the sun and the capacity of the air for absorbing humidity are greatest, or, in other words, that the soil is nowhere artificially watered except when it is so dry that little moisture would be evaporated from it, and, consequently, every acre of irrigated ground is so much added to the evaporable surface of the country. When the supply of water is unlimited, it is allowed, after serving its purpose

---

heavens. And yet the heat of the sun's rays, as measured by sensation, and, at the same time, the evaporation, are greater than they would be with the thermometer at the same point in America. I have frequently felt in Italy, with the mercury below 60° Fahrenheit, and with a mottled and almost opaque sky, a heat of solar irradiation which I can compare to nothing but the scorching sensation experienced in America at a temperature twenty degrees higher, during the intervals between showers, or before a rain, when the clear blue of the sky seems infinite in depth and transparency. Such circumstances may create a necessity for irrigation where it would otherwise be superfluous, if not absolutely injurious.

In speaking of the superior apparent clearness of the *sky* in America, I confine myself to the concave vault of the heavens, and do not mean to assert that terrestrial objects are generally visible at greater distances in the United States than in Italy. Indeed, I am rather disposed to maintain the contrary; for though I know that the lower strata of the atmosphere in Europe never equal in transparency the air near the earth in New Mexico, Peru, and Chili, yet I think the accidents of the coast-line of the Riviera, as, for example, between Nice and La Spezia, and those of the incomparable Alpine panorama seen from Turin, are distinguishable at greater distances than they would be in the United States.

* In our comparatively rainless Western territory, irrigation is extensively and very beneficially employed. In the Salt Lake valley and in California, hundreds if not thousands of miles of irrigation canals have been constructed, and there is little doubt that artificially watering the soil will soon be largely resorted to in the older States. See valuable observations on this subject in HAYDEN, *Preliminary Report on Geological Survey of Wyoming*, 1870, pp. 194, 195, 258-261.

on one field, to run into drains, canals, or rivers. But in most regions where irrigation is regularly employed, it is necessary to economize the water; after passing over or through one parcel of ground, it is conducted to another; no more is usually withdrawn from the canals at any one point than is absorbed by the soil it irrigates, or evaporated from it, and, consequently, it is not restored to liquid circulation, except by infiltration or precipitation. We are safe, then, in saying that the humidity evaporated from any artificially watered soil is increased by a quantity bearing a large proportion to the whole amount distributed over it, for most even of that which is absorbed by the earth is immediately given out again either by vegetables or by evaporation; and the hygrometrical and thermometrical condition of the atmosphere in irrigated countries is modified proportionally to the extent of the practice.

It is not easy to ascertain precisely either the extent of surface thus watered, or the amount of water supplied, in any given country, because these quantities vary with the character of the season; but there are not many districts in Southern Europe where the management of the arrangements for irrigation is not one of the most important branches of agricultural labor. The eminent engineer Lombardini describes the system of irrigation in Lombardy as, "every day in summer, diffusing over 550,000 hectares [1,375,000 acres] of land 45,000,000 cubic mètres [nearly 60,000,000 cubic yards] of water, which is equal to the entire volume of the Seine, at an ordinary flood, or a rise of three mètres above the hydrometer at the bridge of La Tournelle at Paris." * Niel states the quantity of land irrigated in the former kingdom of Sardinia, including Savoy, in 1856, at 240,000 hectares, or not much less than 600,000 acres. This is about four-thirteenths of the cultivable soil of the kingdom. According to the same author, the irrigated lands in France did not exceed 100,000 hectares, or 247,000 acres, while those in Lombardy amounted to 450,000 hectares, more than 1,100,000

---

* *Memorie sui progetti per l'estensione dell' Irrigazione, etc.*, *il Politecnico*, for January, 1863, p. 6.

acres.[*] In these three states alone, then, there were more than three thousand square miles of artificially watered land, and if we add the irrigated soils of the rest of Italy,[†] of the Mediterranean islands, of the Spanish peninsula, of Turkey in Europe and in Asia Minor, of Syria, of Egypt and the remainder of Northern Africa, we shall see that irrigation increases the evaporable surface of the Mediterranean basin by a quantity bearing no inconsiderable proportion to the area naturally covered by water within it.

Arrangements are concluded, and new plans proposed, for an immense increase of the lands fertilized by irrigation in France and in Belgium, as well as in Spain and Italy, and there is every reason to believe that the artificially watered soil of the latter country will be doubled, that of France quadrupled, before the end of this century. There can be no doubt that by these operations man is exercising a powerful influence on the soil, on vegetable and animal life, and on climate, and hence that in this, as in many other fields of industry, he is truly a geographical agency.[‡]

---

[*] NIEL, *L'Agriculture des États Sardes*, p. 232. This estimate, it will be observed, is 275,000 acres less than that of Lombardini.

[†] In 1865 the total quantity of irrigated lands in the kingdom of Italy was estimated at 1,357,677 hectares, or 2,000,000 acres, of which one-half is supplied with water by artificial canals. The Canal Cavour adds 250,000 acres to the above amount. The extent of artificially watered ground in Italy is consequently equal to the entire area of the States of Delaware and Rhode Island. —See the official report, *Sulle Bonificazioni, Risaie, ed Irrigazioni*, 1865, p. 269.

[‡] It belongs rather to agriculture than to geography to discuss the quality of the crops obtained by irrigation, or the permanent effects produced by it on the productiveness of the soil. There is no doubt, however, that all crops which can be raised without watering are superior in flavor and in nutritive power to those grown by the aid of irrigation. Garden vegetables, particularly, profusely watered, are so insipid as to be hardly eatable. Wherever irrigation is practised, there is an almost irresistible tendency, especially among ignorant cultivators, to carry it to excess; and in Piedmont and Lombardy, if the supply of water is abundant, it is so liberally applied as sometimes not only to injure the quality of the product, but to drown the plants and diminish the actual weight of the crop. Grass-lands are perhaps an exception to

As near as can be ascertained, the amount of water applied to irrigated lands is scarcely anywhere less than the total precipitation during the season of vegetable growth, and in gen-

---

this remark, as it seems almost impossible to apply too much water to them, provided it be kept in motion and not allowed to stagnate on the surface.

Professor Liebig, in his *Modern Agriculture*, says: "There is not to be found in chemistry a more wonderful phenomenon, one which more confounds all human wisdom, than is presented by the soil of a garden or field. By the simplest experiment, any one may satisfy himself that rain-water filtered through field or garden soil does not dissolve out a trace of potash, silicic acid, ammonia, or phosphoric acid. The soil does not give up to the water one particle of the food of plants which it contains. The most continuous rains cannot remove from the field, except mechanically, any of the essential constituents of its fertility."

"The soil not only retains firmly all the food of plants which is actually in it, but its power to preserve all that may be useful to them extends much farther. If rain or other water holding in solution ammonia, potash, and phosphoric and silicic acids, be brought in contact with soil, these substances disappear almost immediately from the solution; the soil withdraws them from the water. Only such substances are completely withdrawn by the soil as are indispensable articles of food for plants; all others remain wholly or in part in solution."

These opinions were confirmed, soon after their promulgation, by the experimental researches of other chemists, but are now questioned, and they are not strictly in accordance with the alleged experience of agriculturists in those parts of Italy where irrigation is most successfully applied. They believe that the constituents of vegetable growth are washed out of the soil by excessive and long-continued watering. They consider it also established as a fact of observation, that water which has flowed through or over rich ground is more valuable for irrigation than water from the same source, which has not been impregnated with fertilizing substances by passing through soils containing them; and, on the other hand, that water, rich in the elements of vegetation, parts with them in serving to irrigate a poor soil, and is therefore less valuable as a fertilizer of lower grounds to which it may afterward be conducted. See BAIRD SMITH, *Italian Irrigation*, i., p. 25; SCOTT MONCRIEFF, *Irrigation in Southern Europe*, pp. 34, 87, 89; LOMBARDINI, *Sulle Inondazioni*, etc., p. 73; MANGON, *Les Irrigations*, p. 48.

The practice of irrigation—except in mountainous countries where springs and rivulets are numerous—is attended with very serious economical, social, and political evils. The construction of canals and their immensely ramified branches, and the grading and scarping of the ground to be watered, are always expensive operations, and they very often require an amount of capital which can be commanded only by the state, by moneyed corporations, or by very wealthy proprietors; the capacity of the canals must be calculated with eral it much exceeds that quantity. In grass-grounds and in field-culture it ranges from 27 or 28 to 60 inches, while in smaller crops, tilled by hand-labor, it is sometimes carried as high as 300 inches.[*] The rice-grounds and the *marcite* of

---

reference to the area intended to be irrigated, and when they and their branches are once constructed, it is very difficult to extend them, or to accommodate any of their original arrangements to changes in the condition of the soil, or in the modes or objects of cultivation; the flow of the water being limited by the abundance of the source or the capacity of the canals, the individual proprietor cannot be allowed to withdraw water at will, according to his own private interest or convenience, but both the time and the quantity of supply must be regulated by a general system applicable, as far as may be, to the whole area irrigated by the same canal, and every cultivator must conform his industry to a plan which may be quite at variance with his special objects or with his views of good husbandry. The clashing interests and the jealousies of proprietors depending on the same means of supply are a source of incessant contention and litigation, and the caprices or partialities of the officers who control, or of contractors who farm, the canals, lead not unfrequently to ruinous injustice towards individual landholders. These circumstances discourage the division of the soil into small properties, and there is a constant tendency to the accumulation of large estates of irrigated land in the hands of great capitalists, and consequently to the dispossession of the small cultivators, who pass from the condition of owners of the land to that of hireling tillers. The farmers are no longer yeomen, but peasants. Having no interest in the soil which composes their country, they are virtually expatriated, and the middle class, which ought to constitute the real physical and moral strength of the land, ceases to exist as a rural estate, and is found only among the professional, the mercantile, and the industrial population of the cities.—See, on the difficulty of regulating irrigation by law, NEGRI, *Idea su una Legge in materia di Acqua*, 1864; and AGMARD, *Irrigations du Midi de l'Europe*, where curious and important remarks on the laws and usages of the Spanish Moors and the Spaniards, in respect to irrigation, will be found. The Moors were so careful in maintaining the details of their system, that they kept in public offices bronze models of their dams and sluices, as guides for repairs and rebuilding. Some of these models are still preserved.—*Ibidem*, pp. 204, 205. For an account of recent irrigation works in Spain, see SPON, *Dictionary of Engineering*, article *Irrigation*.

[*] NIEL, *Agriculture des États Sardes*, p. 237. Lombardini's computation just given allows eighty-one cubic mètres per day to the hectare [two hundred and sixty cubic yards to the acre], which, supposing the season of irrigation to be one hundred days, is equal to a precipitation of thirty-two inches. But in Lombardy, water is applied to some crops during a longer period than one hundred days; and in the *marcite* it flows over the ground even in winter. According to Boussingault (*Économie Rurale*, ii., p. 246), grass-grounds ought

Lombardy are not included in these estimates of the amount of water applied.*

---

to receive, in Germany, twenty-one centimètres of water per week, and with less than half that quantity it is not advisable to incur the expense of supplying it. The ground is irrigated twenty-five or thirty times, and if the full quantity of twenty-one centimètres is applied, it receives more than two hundred inches of water, or six times the total amount of precipitation. Puvis, quoted by Boussingault, after much research comes to the conclusion that a proper quantity is twenty centimètres [eight inches] applied twenty-five or thirty times, which corresponds with the estimate just stated. Puvis adds—and, as our author thinks, with reason—that this amount might be doubled without disadvantage.—*Ibidem*, ii., p. 248, 249. In some parts of France this quantity is immensely exceeded, and it is very important to observe, with reference to the employment of irrigation in our Northern States, that water is most freely supplied in the *colder* provinces. Thus, in the Vosges, meadows are literally flooded for weeks together, and while in the department of Vaucluse a meadow may receive, in five waterings of six and a half hours each, twenty-one inches of water, in the Vosges it might be deluged for twenty-four hundred hours in six applications, the enormous quantity of thirteen hundred feet of water flowing over it. See the important work of HERVÉ MANGON, *Sur l'emploi des eaux dans les Irrigations*, chap. ix.

Boussingault observes that rain-water is vastly more fertilizing than the water of irrigating canals, and therefore the supply of the latter must be greater. This is explained partly by the different character of the substances held in solution or suspension by the waters of the earth and of the sky, partly by the higher temperature of the latter, and, possibly, partly also by the mode of application—the rain being finely divided in its fall or by striking plants on the ground, river-water flowing in a continuous sheet.

The temperature of the water is thought even more important than its composition. The sources which irrigate the *marcite* of Lombardy—meadows so fertile that less than an acre furnishes grass for a cow the whole year—are very warm. The ground watered by them never freezes, and a first crop, for soiling, is cut from it in January or February. The Canal Cavour—which takes its supply chiefly from the Po at Chivasso, fourteen or fifteen miles below Turin—furnishes water of much higher fertilizing power than that derived from the Dora Baltea and the Sesia, both because it is warmer, and because it transports a more abundant and a richer sediment than the latter streams, which are fed by Alpine ice-fields and melting snows, and which flow, for long distances, in channels ground smooth and bare by ancient glaciers and not now contributing much vegetable mould or fine slime to their waters.

* About one-seventh of the water which flows over the *marcite* is absorbed by the soil of those meadows or evaporated from their surface, and consequently six-sevenths of the supply remain for use on ground at lower levels.

The meteorological effect of irrigation on a large scale, which would seem *prima facie* most probable, would be an increase of precipitation in the region watered.[*] Hitherto scientific observation has recorded no such increase, but in a question of so purely local a character, we must ascribe very great importance to a consideration which I have noticed elsewhere, but which has been frequently overlooked by meteorologists, namely, that vapors exhaled in one district may very probably be condensed and precipitated in another very distant from their source. If then it were proved that an extension of irrigated soil was not followed by an increase of rain-fall in the same territory, the probability that the precipitation was augmented *somewhere* would not be in the least diminished.

But though we cannot show that in the irrigated portions of Italy the summer rain is more abundant than it was before irrigation was practised—for we know nothing of the meteorological conditions of that country at so remote a period—the fact that there is a very considerable precipitation in the summer months in Lombardy is a strong argument in favor of such increase. In the otherwise similar climate of Rumelia and of much of Asia Minor, irrigation is indeed practised, but in a relatively small proportion. In those provinces there is little or no summer rain. Is it not highly probable that the difference between Italy and Turkey in this respect is to be ascribed, in part at least, to extensive irrigation in the former country, and the want of it in the latter? It is true that, in its accessible strata, the atmosphere of Lombardy is extremely dry during the period of irrigation, but it receives an immense quantity of moisture by the evaporation from the watered soil, and the rapidity with which the aqueous vapor is carried up to higher regions—where, if not driven elsewhere by the wind, it would be condensed by the cold into drops of rain or at least visible clouds—is the reason why it is so little perceptible in the air near the ground.*

---

[*] On the pluviometric effect of irrigation, see LOMBARDINI, *Sulle Inondazioni*, etc., p. 72, 74; the same author, *Essai Hydrologique sur le Nil*, p. 32; MESSEDAGLIA, *Analisi dell' opera di Champion*, pp. 96, 97, *note;* and BAIRD SMITH, *Italian Irrigation*, i., pp. 189, 190.

In an article in *Aus der Natur*, vol. 57, p. 443, it is stated that the rain on the Isthmus of Suez has increased since the opening of the canal, and has enlarged the evaporable surface of the country; but this cannot be accepted as an established fact without further evidence.

But the question of an influence on temperature rests on a different ground; for though the condensation of vapor may not take place within days of time and degrees of distance from the hour and the place where it was exhaled from the surface, a local refrigeration must necessarily accompany a local evaporation. Hence, though the summer temperature of Lombardy is high, we are warranted in affirming that it must have been still higher before the introduction of irrigation, and would again become so if that practice were discontinued.†

The quantity of water artificially withdrawn from running streams for the purpose of irrigation is such as very sensibly to affect their volume, and it is, therefore, an important element in the geography of rivers. Brooks of no trifling current are often wholly diverted from their natural channels to supply the canals, and their entire mass of water is completely absorbed or evaporated, so that only such proportion as is transmitted by infiltration reaches the river they originally fed. Irrigation, therefore, diminishes great rivers in warm countries by cutting off their sources of supply as well as by direct abstraction of water from their main channels. We have just seen that the system of irrigation in Lombardy deprives the Po of a quantity of water equal to the total delivery of the Seine at ordinary flood, or, in other words, of the equivalent of a tributary navigable for hundreds of miles by vessels of considerable burden.

---

* Is not the mottled appearance of the upper atmosphere in Italy, which I have already noticed, perhaps due in part to the condensation of the aqueous vapor exhaled by watered ground?

† I do not know that observations have been made on the thermometric influence of irrigation, but I have often noticed that, on the irrigated plains of Piedmont ten miles south of Turin, the morning temperature in summer was several degrees below that marked at the Observatory in the city.

The new canals executed and projected will greatly increase the loss. The water required for irrigation in Egypt is less than would be supposed from the exceeding rapidity of evaporation in that arid climate; for the soil is thoroughly saturated during the inundation, and infiltration from the Nile continues to supply a considerable amount of humidity in the dryest season. Linant Bey computed that, in the Delta, fifteen and one-third cubic yards per day sufficed to irrigate an acre. If we suppose water to be applied for one hundred and fifty days during the season of growth, this would be equivalent to a total precipitation of about seventeen inches and one-third. Taking the area of actually cultivated soil in Egypt at the estimate of 4,500,000 acres, and the average amount of water daily applied in both Upper and Lower Egypt at twelve hundredths of an inch in depth, we have an abstraction of about 74,000,000 cubic yards, which—the mean daily delivery of the Nile being in round numbers 320,000,000 cubic yards—is twenty-three per cent. of the average quantity of water contributed to the Mediterranean by that river.*

In estimating the effect of this abstraction of water upon the volume of great rivers, especially in temperate climates and in countries with a hilly surface, we must remember that all the water thus withdrawn—except that which is absorbed by vegetation, that which enters into new inorganic compounds, and that which is carried off by evaporation—is finally restored to the original current by superficial flow or by infiltration. It is generally estimated that from one-third to one-half of the water applied to the fields is absorbed by the earth, and this, with the deductions just given, is returned to the river by direct infiltration, or descends through invisible channels to moisten lower grounds, and thence in part escapes again into the bed of the river, by similar conduits, or in the form of springs and rivulets. Interesting observations have lately been made on this subject in France and important practical results arrived at. It was maintained that mountain irrigation is not ultimately injurious to that of the plains below, because lands liberally watered in the spring, when the supply is abundant, act as reservoirs, storing up by absorption water which afterwards filters down to lower grounds or escapes into the channel of the river and keeps up its current in the dry summer months, so as to compensate for what, during those months, is withdrawn from it for upland irrigation. Careful investigation showed that though this proposition is not universally true, it is so in many cases, and there can be no doubt that the loss in the volume of rivers by the abstraction of water for irrigation is very considerably less than the measure of the quantity withdrawn.*

---

* The proportion of the waters of the Nile withdrawn for irrigation is greater than this calculation makes it. The quantity required for an acre is less in the Delta than in Upper Egypt, both because the soil of the Delta, to which Linant Bey's estimate applies, lies little higher than the surface of the river, and is partly saturated by infiltration, and because near the sea, in N. L. 30°, evaporation is much less rapid than it is several degrees southwards and in the vicinity of a parched desert.

---

* See VIGAN, *Étude sur les Irrigations*, Paris, 1867; and SCOTT MONCRIEFF, *Irrigation in Southern Europe*, pp. 89, 90.

The brook Ain Musa, which runs through the ruined city of Petra and finally disappears in the sands of Wadi el Araba, is a considerable stream in winter, and the inhabitants of that town were obliged to excavate a tunnel through the rock near the right bank, just above the upper entrance of the narrow Sik, to discharge a part of its swollen current. The sagacity of Dr. Robinson detected the necessity of this measure, though the tunnel, the mouth of which was hidden by brushwood, was not discovered till some time after his visit. I even noticed, near the arch that crosses the Sik, unequivocal remains of a sluice by which the water was diverted to the tunnel. Immense labor was also expended in widening the natural channel at several points below the town, to prevent the damming up and setting back of the water—a fact I believe not hitherto noticed by travellers.

The Fellahheen above Petra still employ the waters of Ain Musa for irrigation, and in summer the superficial current is wholly diverted from its natural channel for that purpose. At this season, the bed of the brook, which is composed of pebbles, gravel, and sand, is dry in the Sik and through the town; but the infiltration is such that water is generally found by digging to a small depth in the channel. Observing these facts in a visit to Petra in the summer, I was curious to know whether the subterranean waters escaped again to daylight, and I followed the ravine below the town for a long distance. Not very far from the upper entrance of the ravine, arborescent vegetation appeared upon its bottom, and as soon as the ground was well shaded, a thread

Irrigation, as employed for certain special purposes in Europe and America, is productive of very prejudicial climatic effects. I refer particularly to the cultivation of rice in the Southern States of the American Union and in Italy. The climate of the Southern States is in general not necessarily unhealthy for the white man, but he can scarcely sleep a single night in the vicinity of the rice-grounds without being attacked by a dangerous fever. The neighborhood of the rice-fields is possibly less pestilential in Lombardy and Piedmont than in South Carolina and Georgia, but still very insalubrious to both man and beast. "Not only does the population decrease where rice is grown," says Escourrou-Milliago, "but even the flocks are attacked by typhus. In the rice-grounds the soil is divided into compartments rising in gradual succession to the level of the irrigating canal, in order that the water, after having flowed one field, may be drawn off to another, and thus a single current serve for several compartments, the lowest field, of course, still being higher than the ditch which at last drains both it and the adjacent soil. This arrangement gives a certain force of hydrostatic pressure to the water with which the rice is irrigated, and the infiltration from these fields is said to extend through neighboring grounds, sometimes to the distance of not less than a myriamètre, or six English miles, and to be destructive to crops and even trees reached by it. Land thus affected can no longer be employed for any purpose but growing rice, and when prepared for that crop, it propagates still further the evils under which it had itself suffered, and, of course, the mischief is a growing one." *

---

of water burst out. This was joined by others a little lower down, and, at the distance of a mile from the town, a strong current was formed and ran down towards Wadi el Araba.

Similar facts are observed in all countries where the superficial current of water-courses is diverted from their bed for irrigation, but this case is of special interest because it shows the extent of absorption and infiltration even in the torrid climate of Arabia. See Baird Smith, *Italian Irrigation*, vol. i., pp. 172, 386 and 387.

* Escourrou-Milliago, *L'Italie à propos de l'Exposition de Paris*, 1856, p. 92. According to an article in the Gazzetta di Torino for the 17th of

Salts deposited by Water of Irrigation.

The attentive traveller in Egypt and Nubia cannot fail to notice many localities, generally of small extent, where the soil is rendered infertile by an excess of saline matter in its composition. In many cases, perhaps in all, these barren spots lie rather above the level usually flooded by the inundations of the Nile, and yet they exhibit traces of former cultivation. Observations in India suggest a possible explanation of this fact. A saline efflorescence called "Reh" and "Kuller" is gradually invading many of the most fertile districts of Northern and Western India, and changing them into sterile deserts. It consists principally of sulphate of soda (Glauber's salts), with varying proportions of common salt. These salts (which in small quantities are favorable to fertility of soil) are said to be the gradual result of concentration by evaporation of river and canal waters, which contain them in very minute quantities,

---

January, 1869, the deaths from malarious fever in the Canavese district—which is asserted to have been altogether free from this disease before the recent introduction of rice-culture—between the 1st of January and the 15th of October, 1868, were two thousand two hundred and fifty. The extent of the injurious influence of this very lucrative branch of rural industry in Italy is contested by the rice-growers. But see Secondo Laura, *Le Risaje*, Torino, 1869; Selmi, *Il Miasma Palustre*, p. 89; and especially Carlo Livi, *Della coltivazione del Riso in Italia*, in the *Nuova Antologia* for July, 1871, p. 599 *et seqq.*

According to official statistics, the rice-grounds of Italy, including the islands, amounted in 1866 to 450,000 acres. It is an interesting fact in relation to geographical and climatic conditions, that while little rice is cultivated *south* of N. L. 44° in Italy, little is grown in the United States *north* of 35°. To the southward of the great alluvial plain of the Po, the surface is in general too much broken to admit of the formation of level fields of much extent, and where the ground is suitable, the supply of water is often insufficient.

The Moors introduced the cultivation of rice into Spain at an early period of their dominion in that country. The Spaniards sowed rice in Lombardy and in the Neapolitan territory in the 16th century; but besides the want of water and of level ground convenient for irrigation, rice-husbandry has proved so much more pestilential in Southern than in Northern Italy that it has long been discouraged by the Neapolitan government.

and with which the lands are either irrigated or occasionally overflowed. The river inundations in hot countries usually take place but once in a year, and, though the banks remain submerged for days or even weeks, the water at that period, being derived principally from rains and snows, must be less highly charged with mineral matter than at lower stages, and besides, it is always in motion. The water of irrigation, on the other hand, is applied for many months in succession, it is drawn from rivers and canals at the seasons when the proportion of salts is greatest, and it either sinks into the superficial soil, carrying with it the saline substances it holds in solution, or is evaporated from the surface, leaving them upon it. Hence irrigation must impart to the soil more salts than natural inundation. The sterilized grounds in Egypt and Nubia lying above the reach of the floods, as I have said, we may suppose them to have been first cultivated in that remote antiquity when the Nile valley received its earliest inhabitants, and when its lower grounds were in the condition of morasses. They must have been artificially irrigated from the beginning; they may have been under cultivation many centuries before the soil at a lower level was invaded by man, and hence it is natural that they should be more strongly impregnated with saline matter than fields which are exposed every year, for some weeks, to the action of running water so nearly pure that it would be more likely to dissolve salts than to deposit them.

Subterranean Waters.

I have frequently alluded to a branch of physical geography, the importance of which is but recently adequately recognized —the subterranean waters of the earth considered as stationary reservoirs, as flowing currents, and as filtrating fluids. The earth drinks in moisture by direct absorption from the atmosphere, by the deposition of dew, by rain and snow, by percolation from rivers and other superficial bodies of water, and sometimes by currents flowing into caves or smaller visible apertures.[*] Some of this humidity is exhaled again by the

---

[*] The great limestone plateau of the Karst in Carniola is completely honeycombed by caves through which the drainage of that region is conducted. Rivers of considerable volume pour into some of these caves and can be traced underground to their exit. Thus the Recca has been satisfactorily identified with a stream flowing through the cave of Trebich, and with the Timavo—the Timavus of Virgil and the ancient geographers—which empties through several mouths into the Adriatic between Trieste and Aquileia. The city of Trieste is very insufficiently supplied with fresh water. It has been thought practicable to supply this want by tunnelling through the wall of the plateau, which rises abruptly in the rear of the town, until some subterranean stream is encountered, the current of which can be conducted to the city. More visionary projectors have gone further, and imagined that advantage might be taken of the natural tunnels under the Karst for the passage of roads, railways, and even navigable canals. But however chimerical these latter schemes may seem, there is every reason to believe that art might avail itself of these galleries for improving the imperfect drainage of the champaign country bounded by the Karst, and that stopping or opening the natural channels might very much modify the hydrography of an extensive region. See in *Aus der Natur*, xx., pp. 250-254, 263-266, two interesting articles founded on the researches of Schmidt.

The cases are certainly not numerous where marine currents are known to pour continuously into cavities beneath the surface of the earth, but there is at least one well-authenticated instance of this sort—that of the mill-streams at Argostoli in the island of Cephalonia. It had been long observed that the sea-water flowed into several rifts and cavities in the limestone rocks of the coast, but the phenomenon has excited little attention until very recently. In 1833, three of the entrances were closed, and a regular channel, sixteen feet long and three feet wide, with a fall of three feet, was cut into the mouth of a larger cavity. The sea-water flowed into this canal, and could be followed eighteen or twenty feet beyond its inner terminus, when it disappeared in holes and clefts in the rock.

In 1858 the canal had been enlarged to the width of five feet and a half, and a depth of a foot. The water pours rapidly through the canal into an irregular depression and forms a pool, the surface of which is three or four feet below the adjacent soil, and about two and a half or three feet below the level of the sea. From this pool it escapes through several holes and clefts in the rock, and has not yet been found to emerge elsewhere.

There is a tide at Argostoli of about six inches in still weather, but it is considerably higher with a south wind. I do not find it stated whether water flows through the canal into the cavity at low tide, but it distinctly appears that there is no refluent current, as of course there could not be from a basin so much below the sea. Mousson found the delivery through the canal to be at the rate of 24.88 cubic feet to the second; at what stage of the tide does soil, some is taken up by organic growths and by inorganic compounds, some poured out upon the surface by springs and either immediately evaporated or carried down to larger streams and to the sea, some flows by subterranean courses into the bed of fresh-water rivers * or of the ocean, and some remains, though even here not in forever motionless repose, to fill deep cavities and underground channels. In every case

---

not appear. Other mills of the same sort have been erected, and there appear to be several points on the coast where the sea flows into the land.

Various hypotheses have been suggested to explain this phenomenon, some of which assume that the water descends to a great depth beneath the crust of the earth; but the supposition of a difference of level in the surface of the sea on the opposite sides of the island, which seems confirmed by other circumstances, is the most obvious method of explaining these singular facts. If we suppose the level of the water on one side of the island to be raised by the action of currents three or four feet higher than on the other, the existence of cavities and channels in the rock would easily account for a subterranean current beneath the island, and the apertures of escape might be so deep or so small as to elude observation. See *Aus der Natur*, vol. xix., pp. 129 *et seqq.* I have lately been informed by a resident of the Ionian Islands, who is familiar with the locality, that the sea flows uninterruptedly into the sub-insular cavities, at all stages of the tide.

* "The affluents received by the Seine below Rouen are so inconsiderable, that the augmentation of the volume of that river must be ascribed principally to springs rising in its bed. This is a point of which engineers now take notice, and M. Belgrand, the able officer charged with the improvement of the navigation of the Seine between Paris and Rouen, has devoted much attention to it."—BABINET, *Études et Lectures*, iii., p. 185.

On page 232 of the volume just quoted, the same author observes: "In the lower part of its course, from the falls of the Oise, the Seine receives so few important affluents, that evaporation alone would suffice to exhaust all the water which passes under the bridges of Paris."

This supposes a much greater amount of evaporation than has been usually computed, but I believe it is well settled that the Seine conveys to the sea much more water than is discharged into it by all its superficial branches. Babinet states the evaporation from the surface of water at Paris to be twice as great as the precipitation.

Belgrand supposes that the floods of the Seine at Paris are not produced by the superficial flow of the water of precipitation into its channel, but from the augmented discharge of its remote mountain sources, when swollen by the rains and melted snows which percolate through the permeable strata in its upper course.—*Annales des Ponts et Chaussées*, 1851, vol. i.

the aqueous vapors of the air are the ultimate source of supply, and all these hidden stores are again returned to the atmosphere by evaporation.

The proportion of the water of precipitation taken up by direct evaporation from the surface of the ground seems to have been generally exaggerated, sufficient allowance not being made for moisture carried downwards or in a lateral direction, by infiltration or by crevices in the superior rocky or earthy strata. According to Wittwer, Mariotte found that but one-sixth of the precipitation in the basin of the Seine was delivered into that sea by the river, "so that five-sixths remained for evaporation and consumption by the organic world." * Maury estimates the annual amount of precipitation in the valley of the Mississippi at 620 cubic miles, the discharge of that river into the sea at 107 cubic miles, and concludes that "this would leave 513 cubic miles of water to be evaporated from this river-basin annually." † In these and other like computations, the water carried down into the earth by capillary and larger conduits is wholly lost sight of, and no thought is bestowed upon the supply for springs, for common and artesian wells, and for underground rivers, like those in the great caves of Kentucky, which may gush up in fresh-water currents at the bottom of the Caribbean Sea, or rise to the light of day in the far-off peninsula of Florida.‡

---

* *Physicalische Geographie*, p. 286. It does not appear whether this inference is Mariotte's or Wittwer's. I suppose it is a conclusion of the latter.

According to Vallès, the Seine discharges into the sea thirty per cent. of the precipitation in its valley, while the Po delivers into the Adriatic two-thirds and perhaps even three-quarters of the total down-fall of its basin. The differences between the tributaries of the Mississippi in this respect are remarkable, the Missouri discharging only fifteen per cent., the Yazoo not less than ninety. The explanation of these facts is found in the geographical and geological character of the valleys of these rivers. The Missouri flows with a rapid current through an irregular country, the Yazoo has a very slow flow through a low, alluvial region which is kept constantly almost saturated by infiltration.

† *Physical Geography of the Sea.* Tenth edition. London, 1861, § 274.

‡ In the low peninsula of Florida, rivers, which must have their sources

The progress of the emphatically modern science of geology has corrected these erroneous views, because the observations on which it depends have demonstrated not only the existence, but the movement, of water in nearly all geological formations, have collected evidence of the presence of large reservoirs at greater or less depths beneath surfaces of almost every character, and have investigated the rationale of the attendant phenomena.* The distribution of these waters has been minutely studied with reference to a great number of localities, and though the actual mode and rate of their vertical and horizontal transmission is still involved in much obscurity, the laws which determine their aggregation are so well understood, that, when the geology of a given district is known, it is not difficult to determine at what depth water will be reached by the borer, and to what height it will rise.

The same principles have been successfully applied to the discovery of small subterranean collections or currents of water, and some persons have acquired, by a moderate knowledge of the superficial structure of the earth combined with long practice, a skill in the selection of favorable places for digging wells which seems to common observers little less

---

in mountains hundreds of miles distant, pour forth from the earth with a volume sufficient to permit steamboats to ascend to their basins of eruption. In January, 1857, a submarine fresh-water river burst from the bottom of the sea not far from the southern extremity of the peninsula, and for a whole month discharged a current not inferior in volume to the river Mississippi, or eleven times the mean delivery of the Po, and more than six times that of the Nile. We can explain this phenomenon only by supposing that the bed of the sea was suddenly burst up by the hydrostatic upward pressure of the water in a deep reservoir communicating with some great subterranean river or receptacle in the mountains of Georgia or of Cuba, or perhaps even in the valley of the Mississippi.—THOMASSY, *Essai sur l'Hydrologie.*

Late southern journals inform us that the creek under the Natural Bridge in Virginia has suddenly disappeared, being swallowed up by newly formed fissures, of unknown depth, in its channel. It does not appear that an outlet for the waters thus absorbed has been discovered, and it is not improbable that they are filling some underground cavity like that which supplied the submarine river just mentioned.

* See especially STOPPANI, *Corso di Geologia*, i., pp. 270 *et seqq.*

than miraculous. The Abbé Paramelle—a French ecclesiastic who devoted himself for some years to this subject and was extensively employed as a well-finder—states, in his work on Fountains, that in the course of thirty-four years he had pointed out more than ten thousand subterranean springs, and though his geological speculations were often erroneous, high scientific authorities have testified to the great practical value of his methods, and the general accuracy of his predictions.[*]

Hydrographical researches have demonstrated the existence of subterranean currents and reservoirs in many regions where superficial geology had not indicated their probable presence. Thus, a much larger proportion of the precipitation in the valley of the Tiber suddenly disappears than can be accounted for by evaporation and visible flow into the channel of the river. Castelli suspected that the excess was received by underground caverns, and slowly conducted by percolation to the bed of the Tiber. Lombardini—than whom there is no higher authority—concludes that the quantity of water gradually discharged into the river by subterranean conduits, is not less than three-quarters of the total delivery of its basin.[†]

What is true of the hydrology of the Tiber is doubtless more or less true of that of other rivers, and the immense value of natural arrangements which diminish the danger of sudden floods by retaining a large proportion of the precipitation, and of an excessive reduction of river currents in the droughts of summer, by slowly conducting into their beds water accumulated and stored up in subterranean reservoirs in rainy seasons, is too obvious to require to be dwelt upon.

The readiness with which water not obstructed by impermeable strata diffuses itself through the earth in all directions—and, consequently, the importance of keeping up the supply of subterranean reservoirs—find a familiar illustration in the effect of paving the ground about the stems of vines and trees. The surface-earth around the trunk of a tree may be made almost impervious to water, by flagstones and cement, for a distance as great as the spread of the roots; and yet the tree will not suffer for want of moisture, except in droughts severe enough sensibly to affect the supply in deep wells and springs. Both forest and fruit trees attain a considerable age and size in cities where the streets and courts are closely paved, and where even the lateral access of water to the roots is more or less obstructed by deep cellars and foundation walls. The deep-lying veins and sheets of water, supplied by infiltration from often comparatively distant sources, send up moisture by capillary attraction, and the pavement prevents the soil beneath it from losing its humidity by evaporation. Hence, city-grown trees find moisture enough for their roots, and though plagued with smoke and dust, often retain their freshness, while those planted in the open fields, where sun and wind dry up the soil faster than the subterranean fountains can water it, are withering from drought.[*] Without the help of artificial conduit or of water-carrier, the Thames and the Seine refresh the ornamental trees that shade the thoroughfares of London and of Paris, and beneath the hot and reeking mould of Egypt, the Nile sends currents to the extremest border of its valley.[†]

---

[*] Paramelle, *Quellenkunde, mit einem Vorwort von* B. Cotta. 1856.

[†] See Lombardini, *Importanza degli studi sulla Statistica da Fiumi*, p. 27; also, same author, *Sulle Inondazioni avvenute in Francia*, etc., p. 29.

---

[*] The roots of trees planted in towns do not depend exclusively on infiltration for their supply of water, for they receive a certain amount of both moisture and air through the interstices between the paving-stones; but where wide surfaces of streets and courts are paved with air and water tight asphaltum, as in Paris, trees suffer from the diminished supply of these necessary elements.

[†] See the interesting observations of KRIEGK on this subject, *Schriften zur allgemeinen Erdkunde*, cap. iii., § 6, and especially the passages in RITTER's *Erdkunde*, vol. i., there referred to.

The tenacity with which the parched soil of Egypt retains the supply of moisture it receives from the Nile is well illustrated by observations of Girard cited by Lombardini from the *Mémoires de l'Académie des Sciences*, t. ii., 1817. Girard dug wells at distances of 3,200, 1,800, and 1,200 mètres from the Nile, and after three months of low water in the river, found water in the most remote well, at 4^{m}. 97, in the next at 4^{m}. 23, and in that nearest the bank at 3^{m}. 44

Artesian Wells.

The existence of artesian wells depends upon that of subterranean reservoirs and rivers, and the supply yielded by borings is regulated by the abundance of such sources. The waters of the earth are, in many cases, derived from superficial

---

above the surface of the Nile. The fact that the water was highest in the most distant well appears to show that it was derived from the inundation and not, by lateral infiltration, from the river. But water is found beneath the sands at points far above and beyond the reach of the inundations, and can be accounted for only by subterranean percolation from the Nile. At high flood, the hydrostatic pressure on the banks, combined with capillary attraction, sends water to great horizontal distances through the loose soil; at low water the current is reversed, and the moisture received from the river is partly returned, and may often be seen oozing from the banks into the river. —Clot Bey, *Aperçu sur l'Egypte*, i., 128.

Laurent (*Mémoires sur le Sahara Oriental*, pp. 8, 9), in speaking of a river at El-Faid, "which, like all those of the desert, is, most of the time, without water," observes, that many wells are dug in the bed of the river in the dry season, and that the subterranean supply of water thus reached extends itself laterally, at about the same level, at least a kilomètre from the river, as water is found by digging to the depth of twelve or fifteen mètres at a village situated at that distance from the bank.

Recent experiments, however, have shown that in the case of rivers flowing through thickly peopled regions, and especially where the refuse from industrial establishments is discharged into them, the finely comminuted material received from sewers and factories sometimes clogs up the interstices between the particles of sand and gravel which compose the bed and banks, and the water is consequently confined to the channel and no longer diffuses itself laterally through the adjacent soil. This obstruction of course acts in both directions, according to circumstances. In one case, it prevents the escape of river-water and tends to maintain a full flow of the current; in another it intercepts the supply the river might otherwise receive by infiltration from the land, and thus tends to reduce the volume of the stream. In some instances, pits have been sunk along the banks of large rivers and the water which filters into them pumped up to supply aqueducts. This method often succeeds, but where the bed of the stream has been rendered impervious by the discharge of impurities into it, it cannot be depended upon.

The tubular wells generally known as the *American* wells furnish another proof of the free diffusion and circulation of water through the soil. I do not know the date of the first employment of these tubes in the United States, but as early as 1861, the Chevalier Calandra used wooden tubes for this purcurrents which are seen to pour into chasms opened, as it were, expressly for their reception; and in others, where no apertures in the crust of the earth have been detected, their existence is proved by the fact that artesian wells sometimes bring up from great depths seeds, leaves, and even living fish, which must have been carried down through channels large enough

---

pose in Piedmont, with complete success. See the interesting pamphlet, *Sulla Estrazione delle Acque Sotterranee*, by C. CALANDRA. Torino, 1867.

The most remarkable case of infiltration known to me by personal observation is the occurrence of fresh water in the beach-sand on the eastern side of the Gulf of Akaba, the eastern arm of the Red Sea. If you dig a cavity in the beach near the sea-level, it soon fills with water so fresh as not to be undrinkable, though the sea-water two or three yards from it contains even more than the average quantity of salt. It cannot be maintained that this is sea-water freshened by filtration through a few feet or inches of sand, for salt-water cannot be deprived of its salt by that process. It can only come from the highlands of Arabia, and it would seem that there must exist some large reservoir in the interior to furnish a supply which, in spite of evaporation, holds out for months after the last rains of winter, and perhaps even through the year. I observed the fact in the month of June. See ROBINSON, *Biblical Researches*, 1857, vol i., p. 167.

The precipitation in the mountains that border the Red Sea is not known by pluviometric measurement, but the mass of débris brought down the ravines by the torrents proves that their volume must be large. The proportion of surface covered by sand and absorbent earth, in Arabia Petræa and the neighboring countries, is small, and the mountains drain themselves rapidly into the wadies or ravines where the torrents are formed; but the beds of earth and disintegrated rock at the bottom of the valleys are of so loose and porous texture, that a great quantity of water is absorbed in saturating them before a visible current is formed on their surface. In a heavy thunder-storm, accompanied by a deluging rain, which I witnessed at Mount Sinai in the month of May, a large stream of water poured, in an almost continuous cascade, down the steep ravine north of the convent, by which travellers sometimes descend from the plateau between the two peaks, but after reaching the foot of the mountain, it flowed but a few yards before it was swallowed up in the sands.

Fresh-water wells are not unfrequently found upon the borders of ocean beaches. In the dry summer of 1870, drinkable water was procured in many places on the coast of Liguria by digging to the depth of a yard in the beach-sands. Tubular wells reach fresh water at twelve or fifteen feet below the surface on the sandy plains of Cape Cod. In this latter case, the supply is more probably derived directly from precipitation than from lateral infiltration.

to admit a considerable stream.[*] But in general, the sheets and currents of water reached by deep boring appear to be primarily due to infiltration from highlands where the water is first collected in superficial or subterranean reservoirs. By means of channels conforming to the dip of the strata, these reservoirs communicate with the lower basins, and exert upon them a fluid pressure sufficient to raise a column to the surface, whenever an orifice is opened.[†] The water delivered by an artesian well is, therefore, often derived from distant sources, and may be wholly unaffected by geographical or meteorological changes in its immediate neighborhood, while the same changes may quite dry up common wells and springs which are fed only by the local infiltration of their own narrow basins.

In most cases, artesian wells have been bored for purely economical or industrial purposes, such as to obtain good water for domestic use or for driving light machinery, to reach saline or other mineral springs, and recently, in America, to open fountains of petroleum or rock-oil. The geographical and geological effects of such abstraction of fluids from the bowels of the earth are too remote and uncertain to be here noticed;[‡] but artesian wells have lately been employed in Algeria for a purpose which has even now a substantial, and may hereafter acquire a very great geographical importance. It was observed by many earlier as well as recent travellers in the East, among whom Shaw deserves special mention, that the Libyan desert, bordering upon the cultivated shores of the Mediterranean, appeared in many places to rest upon a subterranean lake at an accessible distance below the surface. The Moors are vaguely said to *bore* artesian wells down to this reservoir, to obtain water for domestic use and irrigation, and there is evidence that this art was practised in Northern Africa in the Middle Ages. But it had been lost by the modern Moors, and the universal astonishment and incredulity with which the native tribes viewed the operations of the French engineers sent into the desert for that purpose, are a sufficient proof that this mode of reaching the subterranean waters was new to them. They were, however, aware of the existence of water below the sands, and were dexterous in digging wells—square shafts lined with a framework of palm-tree stems—to the level of the sheet. The wells so constructed, though not technically artesian wells, answer the same purpose;

---

[*] CHARLES MARTINS, *Le Sahara*, in *Revue des Deux Mondes*, Sept. 1, 1864, p. 619; STOPPANI, *Corso di Geologia*, i., 281; DESOR, *Die Sahara*, Basel, 1871, pp. 50, 51.

[†] It is conceivable that in shallow subterranean basins superincumbent mineral strata may rest upon the water and be partly supported by it. In such case the weight of such strata would be an additional, if not the sole, cause of the ascent of the water through the tubes of artesian wells.

The ascent of petroleum in the artesian oil-wells in Pennsylvania, and, in many cases, of salt-water in similar tubes, can hardly be ascribed to hydrostatic pressure, and there is much difficulty in accounting for the rise of water in artesian wells in many parts of the African desert on that principle. Perhaps the elasticity of gases, which probably aids in forcing up petroleum and saline waters, may be, not unfrequently, an agency in causing the flow of water in common artesian borings. It is said that artesian wells lately bored in Chicago. some to the depth of 1,600 feet, raise water to the height of 100 feet above the surface. What is the source of the pressure?

[‡] Many more or less probable conjectures have been made on this subject, but thus far I am not aware that any of the apprehended results have been

---

actually shown to have happened. In an article in the *Annales des Ponts et Chaussées* for July and August, 1839, p. 131, it was suggested that the sinking of the piers of a bridge at Tours in France was occasioned by the abstraction of water from the earth by artesian wells, and the consequent withdrawal of the mechanical support it had previously given to the strata containing it. A reply to this article will be found in VIOLLET, *Théorie des Puits Artésiens*, p. 217.

In some instances the water has rushed up with a force which seemed to threaten the inundation of the neighborhood, and even the washing away of much soil; but in these cases the partial exhaustion of the supply, or the relief of hydrostatic or elastic pressure, has generally produced a diminution of the flow in a short time, and I do not know that any serious evil has ever been occasioned in this way.

In April, 1866, a case of this sort occurred in boring an artesian well near the church of St. Agnes at Venice. When the drill reached the depth of 160 feet, a jet of mud and water was shot up to the height of 130 feet above the surface, and continued to flow with gradually diminishing force for about eight hours.

for the water rises to the surface and flows over it as from a spring.[*]

---

[*] See a very interesting account of these wells, and of the workmen who clean them out when obstructed by sand brought up with the water, in Laurent's memoir on the artesian wells recently bored by the French Government in the Algerian desert, *Mémoire sur le Sahara Oriental*, etc., pp. 19 *et seqq.* Some of the men remained under water from two minutes to two minutes and forty seconds. Several officers are quoted as having observed immersions of three minutes' duration, and M. Berbrugger witnessed one of six minutes and five seconds and another of five minutes and fifty-five seconds. The shortest of these periods is longer than the best pearl-diver can remain below the surface of salt-water. The wells of the Sahara are from twenty to eighty mètres deep.—DESOR, *Die Sahara*, Basel, 1871, p. 43.

The ancient Egyptians were acquainted with the art of boring artesian wells. Ayme, a French engineer in the service of the Pacha of Egypt, found several of these old wells, a few years ago, in the oases. They differed little from modern artesian wells, but were provided with pear-shaped valves of stone for closing them when water was not needed. When freed from the sand and rubbish with which they were choked, they flowed freely and threw up fish large enough for the table. The fish were not blind, as cave-fish often are, but were provided with eyes, and belonged to species common in the Nile. The sand, too, brought up with them resembled that of the bed of that river. Hence it is probable that they were carried to the oases by subterranean channels from the Nile.—DESOR, *Die Sahara*, Basel, 1871, p. 28; STOPPANI, *Corso di Geologia*, i., p. 281. Barth speaks of common wells in Northern Africa from 200 to 360 feet deep.—*Reisen in Africa*, ii., p. 180.

It is certain that artesian wells have been common in China from a very remote antiquity, and the simple method used by the Chinese—where the drill is raised and let fall by a rope, instead of a rigid rod—has lately been employed in Europe with advantage. Some of the Chinese wells are said to be 3,000 feet deep; that of Neusalzwerk in Silesia is 2,300. A well was bored at St. Louis, in Missouri, a few years ago, to supply a sugar refinery, to the depth of 2,199 feet. This was executed by a private firm in three years, at the expense of only $10,000. Four years since the boring was recommenced in this well and reached a depth of 3,150 feet, but without a satisfactory result. Another artesian well was sunk at Columbus, in Ohio, to the depth of 2,500 feet, but without obtaining the desired supply of water. Perhaps, however, the artesian well of the greatest depth ever executed until very recently, is that bored within the last six or seven years, for the use of an Insane Asylum near St. Louis. This well descends to the depth of three thousand eight hundred and forty-three feet, but the water which it furnishes is small in quantity and of a quality that cannot be used for ordinary domestic purposes. The bore has a diameter of six inches to the depth of 425 feet, and after that it is reduced to four inches. For about three thousand feet the strata penetrated

These wells, however, are too few and too scanty in supply to serve any other purposes than the domestic wells of other countries, and it is but recently that the transformation of desert into cultivable land by this means has been seriously attempted. The French Government has bored a large number of artesian wells in the Algerian desert within a few years,

---

were of carboniferous and magnesian limestone alternating with sandstone. The remainder of the well passes through igneous rock. At St. Louis the Missouri and Mississippi rivers are not more than twenty miles distant from each other, and it is worthy of note that the waters of neither of these two rivers appear to have opened for themselves a considerable subterranean passage through the rocky strata of the peninsula which separates them.

When in boring an artesian well water is not reached at a moderate depth, it is not always certain that it will be found by driving the drill still lower. In certain formations, water diminishes as we descend, and it seems probable that, except in case of caverns and deep fissures, the weight of the superincumbent mineral strata so compresses the underlying ones, at no very great distance below the surface, as to render them impermeable to water and consequently altogether dry. See *London Quarterly Journal of Science*, No. xvii., Jan., 1868, p. 18, 19.

In the silver mines of Nevada water is scarcely found at depths below 1,000 feet, and at 1,200 feet from the surface the earth is quite dry.—*American Annual of Scientific Discovery* for 1870, p. 75.

Similar facts are observed in Australia. The *Pleasant Creek News* writes: "A singular and unaccountable feature in connection with our deep quartz mines is being developed daily, which must surprise those well experienced in mining matters. It is the decrease of water as the greater depths are reached. In the Magdala shaft at 950 ft. the water has decreased to a *minimum*; in the Crown Cross Reef Company's shaft, at 800 ft., notwithstanding the two reefs recently struck, no extra water has been met with; and in the long drive of the Extended Cross Reef Company, at a depth of over 800 ft., the water is lighter than it was nearer the surface."

Boring has been carried to a great depth at Sperenberg near Berlin, where, in 1871, the drill had descended 5,500 feet below the surface, passing through a stratum of salt for the last 3,200 feet; but the drilling was still in progress, the whole thickness of the salt-bed not having been penetrated.—*Aus der Natur*, vol. 55, p. 208.

The facts that there are mines extending two miles under the bed of the sea, which are not particularly subject to inconvenience from water, that little water was encountered in the Mt. Cenis tunnel, 3500 feet below the surface, and that at Scarpa, not far from Tivoli, there is an ancient well 1700 feet deep with but eighteen feet of water, may also be cited as proofs that water is not universally diffused at great distances beneath the surface.

and the native sheikhs are beginning to avail themselves of the process. Every well becomes the nucleus of a settlement proportioned to the supply of water, and before the end of the year 1860, several nomade tribes had abandoned their wandering life, established themselves around the wells, and planted more than 30,000 palm trees, besides other perennial vegetables.* The water is found at a small depth, generally from 100 to 200 feet, and though containing too large a proportion of mineral matter to be acceptable to a European palate, it answers well for irrigation, and does not prove unwholesome to the natives.

The most obvious use of artesian wells in the desert at present is that of creating stations for the establishment of military posts and halting-places for the desert traveller; but if the supply of water shall prove adequate for the indefinite extension of the system, it is probably destined to produce a greater geographical transformation than has ever been effected by any scheme of human improvement.

The most striking contrast of landscape scenery that nature brings near together in time or place, is that between the greenery of the tropics, or of a northern summer, and the snowy pall of leafless winter. Next to this in startling novelty of effect, we must rank the sudden transition from the shady and verdant oasis of the desert to the bare and burning party-colored ocean of sand and rock which surrounds it.* The most sanguine believer in indefinite human progress hardly expects that man's cunning will accomplish the universal fulfilment of the prophecy, "the desert shall blossom as the rose," in its literal sense; but sober geographers have thought the future conversion of the sand plains of Northern Africa into fruitful gardens, by means of artesian wells, not an improbable expectation. They have gone farther, and argued that, if the soil were covered with fields and forests, vegetation would call down moisture from the Libyan sky, and that the showers which are now wasted on the sea, or so often deluge Southern Europe with destructive inundation, would in part be condensed over the arid wastes of Africa, and thus, without further aid from man, bestow abundance on regions which nature seems to have condemned to perpetual desolation.

---

* "In the anticipation of our success at Oum-Thiour, everything had been prepared to take advantage of this new source of wealth without a moment's delay. A division of the tribe of the Selmia, and their sheikh, Aïssa ben Shâ, laid the foundation of a village as soon as the water flowed, and planted twelve hundred date-palms, renouncing their wandering life to attach themselves to the soil. In this arid spot, life had taken the place of solitude, and presented itself, with its smiling images, to the astonished traveller. Young girls were drawing water at the fountain; the flocks, the great dromedaries with their slow pace, the horses led by the halter, were moving to the watering trough; the hounds and the falcons enlivened the group of party-colored tents, and living voices and animated movement had succeeded to silence and desolation."—LAURENT, *Mémoires sur le Sahara*, p. 85.

Between 1856 and 1864 the French engineers had bored 83 wells in the Hodna and the Sahara of the Province of Constantine, yielding, all together, 9,000 gallons a minute, and irrigating more than 125,000 date-palms.—RECLUS, *La Terre*, i., p. 110.

---

* The variety of hues and tones in the local color of the desert is, I think, one of the phenomena which most surprise and interest a stranger to those regions. In England and the United States, rock is so generally covered with moss or earth, and earth with vegetation, that untravelled Englishmen and Americans are not very familiar with naked rock as a conspicuous element of landscape. Hence, in their conception of a bare cliff or precipice, they hardly ascribe definite color to it, but depict it to their imagination as wearing a neutral tint not assimilable to any of the hues with which nature tinges her atmospheric or paints her organic creations. There are certainly extensive desert ranges, chiefly limestone formations, where the surface is either white, or has weathered down to a dull uniformity of tone which can hardly be called color at all; and there are sand plains and drifting hills of wearisome monotony of tint. But the chemistry of the air, though it may tame the glitter of the limestone to a dusky gray, brings out the green and brown and purple of the igneous rocks, and the white and red and blue and violet and yellow of the sandstone. Many a cliff in Arabia Petræa is as manifold in color as the rainbow, and the veins are so variable in thickness and inclination, so contorted and involved in arrangement, as to bewilder the eye of the spectator like a disk of party-colored glass in rapid evolution.

In the narrower wadies the mirage is not common; but on broad expanses, as at many points between Cairo and Suez, and in Wadi el Araba, it mocks you with lakes and land-locked bays, studded with islands and fringed with trees, all painted with an illusory truth of representation absolutely indistinguishable from the reality. The checkered earth, too, is canopied with a heaven as variegated as itself. You see, high up in the sky, rosy clouds at noonday, colored probably by reflection from the ruddy mountains, while near the horizon float cumuli of a transparent, ethereal blue, seemingly balled up out of the clear cerulean substance of the firmament, and detached from the heavenly vault, not by color or consistence, but solely by the light and shade of their salient and retreating outlines.

An equally bold speculation, founded on the well-known fact that the temperature of the earth and of its internal waters increases as we descend beneath the surface, has suggested that artesian wells might supply heat for industrial and domestic purposes, for hot-house cultivation, and even for the local amelioration of climate. The success with which Count Lardarel has employed natural hot springs for the evaporation of water charged with boracic acid, and other fortunate applications of the heat of thermal sources, lend some countenance to the latter project; but both must, for the present, be ranked among the vague possibilities of science, not regarded as probable future triumphs of man over nature.

Artificial Springs.

A more plausible and inviting scheme is that of the creation of perennial springs by husbanding rain and snow water, storing it up in artificial reservoirs of earth, and filtering it through purifying strata, in analogy with the operations of nature. The sagacious Palissy—starting from the theory that all springs are primarily derived from precipitation, and reasoning justly on the accumulation and movement of water in the earth—proposed to reduce theory to practice, and to imitate the natural processes by which rain is absorbed by the earth and given out again in running fountains. "When I had long and diligently considered the cause of the springing of natural fountains and the places where they be wont to issue," says he, "I did plainly perceive, at last, that they do proceed and are engendered of nought but the rains. And it is this, look you, which hath moved me to enterprise the gathering together of rain-water after the manner of nature, and the most closely according to her fashion that I am able; and I am well assured that by following the formulary of the Supreme Contriver of fountains, I can make springs, the water whereof shall be as good and pure and clear as of such which be natural." * Palissy discusses the subject of the origin of springs at length and with much ability, dwelling specially on infiltration, and, among other things, thus explains the frequency of springs in mountainous regions: "Having well considered the which, thou mayest plainly see the reason why there be more springs and rivulets proceeding from the mountains than from the rest of the earth; which is for no other cause but that the rocks and mountains do retain the water of the rains like vessels of brass. And the said waters falling upon the said mountains descend continually through the earth, and through crevices, and stop not till they find some place that is bottomed with stone or close and thick rocks; and they rest upon such bottom until they find some channel or other manner of issue, and then they flow out in springs or brooks or rivers, according to the greatness of the reservoirs and of the outlets thereof." †

After a full exposition of his theory, Palissy proceeds to describe his method of creating springs, which is substantially the same as that lately proposed by Babinet in the following terms: "Choose a piece of ground containing four or five acres, with a sandy soil, and with a gentle slope to determine the flow of the water. Along its upper line, dig a trench five or six feet deep and six feet wide. Level the bottom of the trench, and make it impermeable by paving, by macadamizing, by bitumen, or, more simply and cheaply, by a layer of clay. By the side of this trench dig another, and throw the earth from it into the first, and so on until you have rendered the

---

* *Œuvres de Palissy*, *Des Eaux et Fontaines*, p. 157.

† Id., p. 166. Palissy's method has recently been tried with good success in various parts of France.

subsoil of the whole parcel impermeable to rain-water. Build a wall along the lower line with an aperture in the middle for the water, and plant fruit or other low trees upon the whole, to shade the ground and check the currents of air which promote evaporation. This will infallibly give you a good spring which will flow without intermission, and supply the wants of a whole hamlet or a large chateau." * Babinet states that the whole amount of precipitation on a reservoir of the proposed area, in the climate of Paris, would be about 13,000 cubic yards, not above one half of which, he thinks, would be lost, and, of course, the other half would remain available to supply the spring. I much doubt whether this expectation would be realized in practice, in its whole extent; for if Babinet is right in supposing that the summer rain is wholly evaporated, the winter rains, being much less in quantity, would hardly suffice to keep the earth saturated and give off so large a surplus.

The method of Palissy, though, as I have said, similar in principle to that of Babinet, would be cheaper of execution, and, at the same time, more efficient. He proposes the construction of relatively small filtering receptacles, into which he would conduct the rain falling upon a large area of rocky hillside, or other sloping ground not readily absorbing water. This process would, in all probability, be a very successful, as well as an inexpensive, mode of economizing atmospheric precipitation, and compelling the rain and snow to form perennial fountains at will.

---

* Babinet, *Études et Lectures sur les Sciences d'Observation*, ii., p. 225. Our author precedes his account of his method with a complaint which most men who indulge in thinking have occasion to repeat many times in the course of their lives. "I will explain to my readers the construction of artificial fountains according to the plan of the famous Bernard de Palissy, who, a hundred and fifty [three hundred] years ago, came and took away from me, a humble academician of the nineteenth century, this discovery which I had taken a great deal of pains to make. It is enough to discourage all invention when one finds plagiarists in the past as well as in the future!" (P. 224.)

Economizing Precipitation.

The methods suggested by Palissy and by Babinet are of limited application, and designed only to supply a sufficient quantity of water for the domestic use of small villages or large private establishments. Dumas has proposed a much more extensive system for collecting and retaining the whole precipitation in considerable valleys, and storing it in reservoirs, whence it is to be drawn for household and mechanical purposes, for irrigation, and, in short, for all the uses to which the water of natural springs and brooks is applicable. His plan consists in draining both surface and subsoil, by means of conduits differing in construction according to local circumstances, but in the main not unlike those employed in improved agriculture, collecting the water in a central channel, securing its proper filterage, checking its too rapid flow by barriers at convenient points, and finally receiving the whole in spacious, covered reservoirs, from which it may be discharged in a constant flow or at intervals as convenience may dictate.*

There is no reasonable doubt that a very wide employment of these various contrivances for economizing and supplying water is practicable, and the expediency of resorting to them is almost purely an economical question. There appears to be no serious reason to apprehend collateral evils from them, and in fact all of them, except artesian wells, are simply indirect methods of returning to the original arrangements of nature, or, in other words, of restoring the fluid circulation of the globe; for when the earth was covered with the forest, perennial springs gushed from the foot of every hill, brooks flowed down the bed of every valley. The partial recovery of the fountains and rivulets which once abundantly watered the face of the agricultural world seems practicable by such means, even without any general replanting of the forests; and the cost of one year's warfare—or in some countries of that armed peace which has been called "Platonic war"—if judiciously expended in a combination of both methods of improvement, would secure, to almost every country that man has exhausted, an amelioration of climate, a renovated fertility of soil, and a general physical improvement, which might almost be characterized as a new creation.

---

* M. G. DUMAS, *La Science des Fontaines*, 1857.

Inundations and Torrents.

In pointing out in a former chapter the evils which have resulted from the too extensive destruction of the forests, I dwelt at some length on the increased violence of river inundations, and especially on the devastations of torrents, in countries improvidently deprived of their woods, and I spoke of the replanting of the forests as probably the most effectual method of preventing the frequent recurrence of disastrous floods. There are many regions where, from the loss of the superficial soil, from financial considerations, and from other special causes, the general restoration of the woods is not, under present circumstances, either possible or desirable. In all inhabited countries, the necessities of agriculture and other considerations of human convenience will always require the occupation of much the largest proportion of the surface for purposes inconsistent with the growth of extensive forests. Even where large plantations are possible and in actual process of execution, many years must elapse before the action of the destructive causes in question can be arrested or perhaps even sensibly mitigated by their influence; and besides, floods will always occur in years of excessive precipitation, whether the surface of the soil be generally cleared or generally wooded.*

---

* All the arrangements of rural husbandry, and we might say of civilized occupancy of the earth, are such as necessarily to increase the danger and the range of floods by promoting the rapid discharge of the waters of precipitation. Superficial, if not subterranean, drainage is a necessary condition of all agriculture. There is no field which has not some artificial disposition for this purpose, and even the furrows of ploughed land, if the surface is inclined, and especially when it is frozen, serve rather to carry off than to retain

Physical improvement in this respect, then, cannot be confined to merely preventive measures, but, in countries subject to damage by inundation, means must be contrived to obviate dangers and diminish injuries to which human life and all the works of human industry will occasionally be exposed, in spite of every effort to lessen the frequency of their recurrence by acting directly on the causes that produce them. As every civilized country is, in some degree, subject to inundation by the overflow of rivers, the evil is a familiar one, and needs no general description. In discussing this branch of the subject, therefore, I may confine myself chiefly to the means that have been or may be employed to resist the force and limit the ravages of floods, which, left wholly unrestrained, would not only inflict immense injury upon the material interests of man, but produce geographical revolutions of no little magnitude.

Inundations of 1856 *in France.*

The month of May, 1856, was remarkable for violent and almost uninterrupted rains, and most of the river-basins of France were inundated to an extraordinary height. In the valleys of the Loire and its affluents, about a million of acres, including many towns and villages, were laid under water, and the amount of pecuniary damage was almost incalculable.* The flood was not less destructive in the valley of the Rhone, and in fact an invasion by a hostile army could hardly have been more disastrous to the inhabitants of the plains than was this terrible deluge. There had been a flood of this latter river in the year 1840, which, for height and quantity of water, was almost as remarkable as that of 1856, but it took place in

---

water. As Becquerel has observed, common road and railway ditches are among the most efficient conduits for the discharge of surface-water which man has yet constructed, and of course they are powerful agents in causing river inundations. All these channels are, indeed, necessary for the convenience of man, but this convenience, like every other interference with the order of nature, must often be purchased at a heavy cost.

* CHAMPION, *Les Inondations en France*, iii., p. 156, note.

the month of November, when the crops had all been harvested, and the injury inflicted by it upon agriculturists was, therefore, of a character to be less severely and less immediately felt than the consequences of the inundation of 1856.*

In the fifteen years between these two great floods, the population and the rural improvements of the river valleys had much increased, common roads, bridges, and railways had been multiplied and extended, telegraph lines had been constructed, all of which shared in the general ruin, and hence greater and more diversified interests were affected by the catastrophe of 1856 than by any former like calamity. The great flood of 1840 had excited the attention and roused the sympathies of the French people, and the subject was invested with new interest by the still more formidable character of the inundations of 1856. It was felt that these scourges had ceased to be a matter of merely local concern, for, although they bore most heavily on those whose homes and fields were situated within the immediate reach of the swelling waters, yet they frequently destroyed harvests valuable enough to be a matter of national interest, endangered the personal security of the population of important political centres, interrupted communication for days and even weeks together on great lines of traffic and travel—thus severing, as it were, all South-western France from the rest of the empire—and finally threatened to produce great and permanent geographical changes. The well-being of the whole commonwealth was seen to be involved in preventing the recurrence and in limiting the range of such devastations. The Government encouraged scientific investigation of the phenomena and their laws. Their causes, their history, their immediate and remote consequences, and the possible safeguards to be employed against them, have been carefully studied by the most eminent physicists, as well as by the ablest theoretical and practical engineers of France. Many hitherto unobserved facts have been collected, many new hypotheses suggested, and many plans, more or less original in character, have been devised for combating the evil; but thus far, the most competent judges are not well agreed as to the mode, or even the possibility, of applying an effectual remedy.

---

* Notwithstanding this favorable circumstance, the damage done by the inundation of 1840 in the valley of the Rhone was estimated at seventy-two millions of francs.—CHAMPION, *Les Inondations en France*, iv., p. 124.

Several smaller floods of the Rhone, experienced at a somewhat earlier season of the year in 1846, occasioned a loss of forty-five millions of francs. "What if," says Dumont, "instead of happening in October, that is, between harvest and seedtime, they had occurred before the crops were secured? The damage would have been counted by hundreds of millions."—*Des Travaux Publics*, p. 99, note.

I have noticed in the next preceding chapter the recent legislation of France upon the preservation and restoration of the forests, with reference to their utility in subduing torrents and lessening the frequency and diminishing the violence of river inundations. The provisions of these laws are preventive rather than remedial, but most beneficial effects have already been experienced from the measures adopted in pursuance of them, though sufficient time has not yet elapsed for the complete execution of the greater operations of the system.

Basins of Reception.

Destructive inundations of large rivers are seldom, if ever, produced by precipitation within the limits of the principal valley, but almost uniformly by sudden thaws or excessive rains on the mountain ranges where the tributaries take their rise. It is therefore plain that any measures which shall check the flow of surface-waters into the channels of the affluents, or which shall retard the delivery of such waters into the principal stream by its tributaries, will diminish in the same proportion the dangers and the evils of inundation by great rivers. The retention of the surface-waters upon or in the soil can hardly be accomplished except by the methods already mentioned, replanting of forests, and furrowing or terracing. The current of mountain streams can be checked by various methods, among which the most familiar and obvious is the erection of barriers or dams across their channels, at points convenient for forming reservoirs large enough to retain the superfluous waters of great rains and thaws.* Besides the utility of such basins in preventing floods, the construction of them is recommended by very strong considerations, such as the furnishing of a constant supply of water for agricultural and mechanical purposes, and, also, their value as ponds for breeding and rearing fish, and, perhaps, for cultivating aquatic vegetables.†

The objections to the general adoption of the system of reservoirs are these: the expense of their construction and maintenance; the reduction of cultivable area by the amount of surface they must cover; the interruption they would occasion to free communication; the probability that they would soon be filled up with sediment, and the obvious fact that when full of earth, or even water, they would no longer serve their principal purpose; the great danger to which they would expose the country below them in case of the bursting of their barriers; ‡ the evil consequences they would occasion by prolonging the flow of inundations in proportion as they diminished their height; the injurious effects it is supposed they would produce upon the salubrity of the neighboring districts; and, lastly, the alleged impossibility of constructing artificial basins sufficient in capacity to prevent, or in any considerable measure to mitigate, the evils they are intended to guard against.

---

* On the construction of temporary and more permanent barriers to the currents of torrents and rivulets, see MARCHAND, *Les Torrents des Alpes*, in *Revue des Eaux et Forêts* for October and November, 1871.

† In reference to the utilization of artificial as well as natural reservoirs, see ACKERHOF, *Die Nutruny der Teiche und Gewässer*, Quadlinburg, 1869.

‡ For accounts of damage from the bursting of reservoirs, see VALLÉE, *Mémoire sur les Reservoirs d'Alimentation des Canaux*, *Annales des Ponts et Chaussées*, 1833, 1er sémestre, p. 261.

The dam of the reservoir of Puentes in Spain, which was one hundred and sixty feet high, after having discharged its functions for eleven years, burst, in 1802, in consequence of a defect in its foundations, and the eruption of the water destroyed or seriously injured eight hundred houses, and produced damage to the amount of more than a million dollars.—AYMARD, *Irrigations du Midi de l'Europe*, pp. 257-259.

The last argument is more easily reduced to a numerical question than the others. The mean and extreme annual precipitation of all the basins where the construction of such works would be seriously proposed is already approximately known by meteorological tables, and the quantity of water, delivered by the greatest floods which have occurred within the memory of man, may be roughly estimated from their visible traces. From these elements, or from meteorological records, the capacity of the necessary reservoirs can be calculated. Let us take the case of the Ardèche. In the inundation of 1857, that river poured into the Rhone 1,305,000,000 cubic yards of water in three days. If we suppose that half this quantity might have been suffered to flow down its channel without inconvenience, we shall have about 650,000,000 cubic yards to provide for by reservoirs. The Ardèche and its principal affluent, the Chassezac, have, together, about twelve considerable tributaries rising near the crest of the mountains which bound the basin. If reservoirs of equal capacity were constructed upon all of them, each reservoir must be able to contain 54,000,000 cubic yards, or, in other words, must be equal to a lake 3,000 yards long, 1,000 yards wide, and 18 yards deep, and besides, in order to render any effectual service, the reservoirs must all have been empty at the commencement of the rains which produced the inundation.

Thus far I have supposed the swelling of the waters to be uniform throughout the whole basin; but such was by no means the fact in the inundation of 1857, for the rise of the Chassezac, which is as large as the Ardèche proper, did not exceed the limits of ordinary floods, and the dangerous excess came solely from the headwaters of the latter stream. Hence reservoirs of double the capacity I have supposed would have been necessary upon the tributaries of that river, to prevent the injurious effects of the inundation. It is evident that the construction of reservoirs of such magnitude for such a purpose is financially, if not physically, impracticable, and when we take into account a point I have just suggested, namely, that the reservoirs must be empty at all times of apprehended flood, and, of course, their utility limited almost solely to the single object of preventing inundations, the total inapplicability of such a measure in this particular case becomes still more glaringly manifest.

Another not less conclusive fact is, that the valleys of all the upland tributaries of the Ardèche descend so rapidly, and have so little lateral expansion, as to render the construction of capacious reservoirs in them quite impracticable. Indeed, engineers have found but two points in the whole basin suitable for that purpose, and the reservoirs admissible at these would have only a joint capacity of about 70,000,000 cubic yards, or less than one-ninth part of what I suppose to be required. The case of the Ardèche is no doubt an extreme one, both in the topographical character of its basin and in its exposure to excessive rains; but all destructive inundations are, in a certain sense, extreme cases also, and this of the Ardèche serves to show that the construction of reservoirs is not by any means to be regarded as a universal panacea against floods.

Nor, on the other hand, is this measure to be summarily rejected. Nature has adopted it on a great scale, on both flanks of the Alps, and on a smaller, on those of the Adirondacks and of many lower chains. The quantity of water which, in great rains or sudden thaws, rushes down the steep declivities of the Alps, is so vast that the channels of the Swiss and Italian rivers would be totally incompetent to carry it off as rapidly as it would pour into them, were it not absorbed by the capacious basins which nature has scooped out for its reception, freed from the transported material which adds immensely both to the volume and to the force of its current, and then, after some reduction by evaporation and infiltration, gradually discharged into the beds of the rivers. In the inundation of 1829, the water discharged into Lake Como from the 15th to the 20th of September amounted to 2,600 cubic yards the second, while the outflow from the lake during the same period was only at the rate of about 1,050 cubic yards to the second. In those five days, then, the lake accumulated 670,000,000 cubic yards of superfluous water, and of course diminished by so much the quantity to be disposed of by the Po.[*] In the flood of October, 1868, the surface of Lago Maggiore was raised twenty-five feet above low-water mark in the course of a few hours.[†] There can be no doubt that without such detention of water by the Lakes Como, Maggiore, Garda, and other subalpine basins, almost the whole of Lombardy would have been irrecoverably desolated, or rather, its great plain would never have become anything but a vast expanse of river-beds and marshes; for the annual floods would always have prevented the possibility of its improvement by man.[‡]

Lake Bourget in Savoy, once much more extensive than it is at present, served, and indeed still serves, a similar purpose in the economy of nature. In a flood of the Rhone, in 1863, this lake received from the overflow of that river, which does not pass through it, 72,000,000 cubic yards of water, and of course moderated, to that extent, the effects of the inundation below.[§]

In fact, the alluvial plains which border the course of most considerable streams, and are overflowed in their inundations, either by the rise of the water to a higher level than that of their banks, or by the bursting of their dikes, serve as safety-valves for the escape of their superfluous waters. The current of the Po, spreading over the whole space between its widely separated embankments, takes up so much water in its inundations, that, while a little below the outlet of the Ticino the discharge of the channel is sometimes not less than 19,500 cubic yards to the second, it has never exceeded 6,730 yards at Ponte Lagoscuro, near Ferrara. The currents of the Mississippi, the Rhone, and of many other large rivers, are modified in the same way. In the flood of 1858, the delivery of the Mississippi, a little below the mouth of the Ohio, was 52,000 cubic yards to the second, but at Baton Rouge, though of course increased by the waters of the Arkansas, the Yazoo, and other smaller tributaries, the discharge was reduced to 46,760 cubic yards. We rarely err when we cautiously imitate the processes of nature, and there are doubtless many cases where artificial basins of reception and lateral expansions of river-beds might be employed with advantage. Many upland streams present points where none of the objections usually urged against artificial reservoirs, except those of expense and of danger from the breaking of dams, could have any application. Reservoirs may be so constructed as to retain the entire precipitation of the heaviest thaws and rains, leaving only the ordinary quantity to flow along the channel; they may be raised to such a height as only partially to obstruct the surface drainage; or they may be provided with sluices by means of which their whole contents can be discharged in the dry season and a summer crop be grown upon the ground they cover at high water. The expediency of employing them and the mode of construction depend on local conditions, and no rules of universal applicability can be laid down on the subject.*

---

[*] BAIRD SMITH, *Italian Irrigation*, i., p. 176.

[†] *Bollettino della Società Geog. Italiana*, iii., p. 466

[‡] See, as to the probable effects of certain proposed hydraulic works at the outlet of Lake Maggiore on the action of the lake as a regulating reservoir, TAGLIASECCHI, *Notizie sui Canali dell' Alta Lombardia*, Milano, 1869.

[§] ELISEÉE RECLUSE, *La Terre*, i., p. 460.

It is remarkable that nations which we, in the inflated pride of our modern civilization, so generally regard as little less than barbarian, should have long preceded Christian Europe in the systematic employment of great artificial basins for the various purposes they are calculated to subserve. The ancient Peruvians built strong walls, of excellent workmanship, across the channels of the mountain sources of important streams, and the Arabs executed immense works of similar description, both in the great Arabian peninsula and in all the provinces of Spain which had the good fortune to fall under their sway. The Spaniards of the fifteenth and sixteenth centuries, who, in many points of true civilization and culture, were far inferior to the races they subdued, wantonly destroyed these noble monuments of social and political wisdom, or suffered them to perish, because they were too ignorant to appreciate their value, or too unskilful as practical engineers to be able to maintain them, and some of their most important territories were soon reduced to sterility and poverty in consequence.

---

* The insufficiency of artificial basins of reception as a means of averting the evils resulting from the floods of great rivers has been conclusively shown, in reference to a most important particular case—that of the Mississippi—by Humphreys and Abbot, in their admirable monograph of that river.

Diversion of Rivers.

Another method of preventing or diminishing the evils of inundation by torrents and mountain rivers, analogous to that employed for the drainage of lakes, consists in the permanent or occasional diversion of their surplus waters, or of their entire currents, from their natural courses, by tunnels or open channels cut through their banks. Nature, in many cases, resorts to a similar process. Most great rivers divide themselves into several arms in their lower course, and enter the sea by different mouths. There are also cases where rivers send off lateral branches to convey a part of their waters into the channel of other streams.* The most remarkable of these is the junction between the Amazon and the Orinoco by the natural canal of the Cassiquiare and the Rio Negro. In India, the Cambodja and the Menam are connected by the Anam; the Saluen and the Irawaddi by the Panlaun. There are similar examples, though on a much smaller scale, in Europe. The Torneă and the Calix rivers in Lapland communicate by the Tarando, and in Westphalia, the Else, an arm of the Haase, falls into the Weser.*

---

* Some geographical writers apply the term *bifurcation* exclusively to this intercommunication of rivers; others, with more etymological propriety, use it to express the division of great rivers into branches at the head of their deltas. A technical word is wanting to designate the phenomenon mentioned in the text, and there is no valid objection to the employment of the anatomical term *anastomosis* for this purpose.

The change of bed in rivers by gradual erosion of their banks is familiar to all, but instances of the sudden abandonment of a primitive channel are by no means wanting. At a period of unknown antiquity, the Ardèche pierced a tunnel 200 feet wide and 100 high, through a rock, and sent its whole current through it, deserting its former bed, which gradually filled up, though its course remained traceable. In the great inundation of 1827, the tunnel proved insufficient for the discharge of the water, and the river burst through the obstructions which had now choked up its ancient channel, and resumed its original course.†

It was probably such facts as these that suggested to ancient engineers the possibility of like artificial operations, and there are numerous instances of the execution of works for this purpose in very remote ages. The Bahr Jusef, the great stream which supplies the Fayoum with water from the Nile, has been supposed, by some writers, to be a natural channel; but both it and the Bahr el Wady are almost certainly artificial canals constructed to water that basin, to regulate the level of Lake Moeris, and possibly, also, to diminish the dangers resulting from excessive inundations of the Nile, by serving as waste-weirs to discharge a part of its overflowing waters.* Several of the seven ancient mouths of the Nile are believed to be artificial channels, and Herodotus even asserts that King Menes diverted the entire course of that river from the Libyan to the Arabian side of the valley. There are traces of an ancient river-bed along the western mountains, which give some countenance to this statement. But it is much more probable that the works of Menes were designed rather to prevent a natural, than to produce an artificial, change in the channel of the river.

---

* The division of the currents of rivers, as a means of preventing the overflow of their banks, is by no means a remedy capable of general application, even when local conditions are favorable to the construction of an emissary. The velocity of a stream, and consequently its delivery in a given time, are frequently diminished in proportion to the diminution of the volume by diversion; and on the other hand, the increase of volume by the admission of a new tributary increases proportionally the velocity and the quantity of water delivered. Emissaries may, nevertheless, often be useful in carrying off water which has already escaped from the channel and which would otherwise become stagnant and prevent further lateral discharge from the main current, and it is upon this principle that Humphreys and Abbot think a canal of diversion at Lake Providence might be advisable. Emissaries serve an important purpose in the lower course of rivers where the bed is nearly a dead level and the water moves from previously acquired momentum and the pressure of the current above, rather than by the force of gravitation, and it is, in general, only under such circumstances, as for example in the deltas at the mouths of great rivers, that nature employs them.

† MARDIGNY, *Mémoire sur les Inondations de l'Ardèche*, p. 13.

Two of the most celebrated cascades in Europe, those of the Teverone at Tivoli and of the Velino at Terni, owe, if not their existence, at least their position and character, to the diversion of their waters from their natural beds into new channels, in order to obviate the evils produced by their frequent floods. Remarkable works of the same sort have been executed in Switzerland, in very recent times. Until the year 1714, the Kander, which drains several large Alpine valleys, ran, for a considerable distance, parallel with the Lake of Thun, and a few miles below the city of that name emptied into the river Aar. It frequently flooded the flats along the lower part of its course, and it was determined to divert it into the Lake of Thun. For this purpose, two parallel tunnels were cut through the intervening rock, and the river turned into them. The violence of the current burst up the roof of the tunnels, and, in a very short time, wore the new channel down not less than one hundred feet, and even deepened the former bed at least fifty feet, for a distance of two or three miles above the tunnel. The lake was two hundred feet deep at the point where the river was conducted into it, but the gravel and sand carried down by sequently, the water of its floods, which would otherwise spread over a wide surface, is confined within narrow limits, the velocity of the current and its transporting power are augmented, and its burden of sand and gravel is deposited at some lower point, where the rapidity of its flow is checked by a dam or other artificial obstruction, by a diminution in the inclination of the bed, by a wider channel, or finally by a lacustrine or marine basin which receives its waters. Wherever it lets fall solid material, its channel is raised in consequence, and the declivity of the whole bed between the head of the embankment and the slack of the stream is reduced. Hence the current, at first accelerated by confinement, is afterwards checked by the mechanical resistance of the matter deposited, and by the diminished inclination of its channel, and then begins again to let fall the earth it holds in suspension, and to raise its bed at the point where its overflow had been before prevented by embankment.* The bank must now be raised in proportion, and

---

* The starting-points of these anals were far up the Nile, and of course at a comparatively high level, and it is probable that they received water only during the inundation. Linant Bey calculates the capacity of Lake Moeris at 3,686,667 cubic yards and the water received by it at high Nile at 465 cubic yards the second.

---

* In proportion as the dikes are improved, and breaches and the escape of the water through them are less frequent, the height of the annual inundations is increased. Some towns on the banks of the Po, and of course within the system of parallel embankments, were formerly secure from flood by the height of the artificial mounds on which they were built; but they have recently been obliged to construct ring-dikes for their protection.

Lombardini lays down the following general statement of the effects of river embankments:

"The immediate effect of embanking a river is generally an increase in the height of its floods, but, at the same time, a depression of its bed, by reason of the increased force, and consequently excavating action, of the current.

"It is true that coarser material may hençe be carried further, and at the same time deposit itself on a reduced slope.

"The embankment of the upper branches of a river increases the volume, and therefore the height of the floods in the lower course, in consequence of the more rapid discharge of its affluents into it.

"When, in consequence of the flow of a river channel through an alluvial soil not yet *regulated*, or, in other words, which has not acquired its normal inclination, the course of the river has not become established, it is natural that its bed should rise more rapidly after its embankment. . . .

"The embankment of the lower course of a river, near its discharge into the sea, causes the elevation of the bed of the next reach above, both because the swelling of the current, in consequence of its lateral confinement, occasions these processes would be repeated and repeated indefinitely, had not nature provided a remedy in floods, which sweep out recent deposits, burst the bonds of the river and overwhelm the adjacent country with final desolation, or divert the current into a new channel, destined to become, in its turn, the scene of a similar struggle between man and the waters.*

But here, as in so many other fields where nature is brought into conflict with man, she first resists his attempts at interference with her operations, then, finding him the stronger, quietly submits to his rule, and ends by contributing her aid to strengthen the walls and shackles by which he essays to confine her. If, by assiduous repair of his dikes, he, for a considerable time, restrains the floods of a river within new bounds, nature, by a series of ingenious compensations, brings the fluctuating bed of the stream to a substantially constant level, and

---

eddies, and of course deposits, and because the prolongation of the course of the stream, or the advance of its delta into the sea, is accelerated."—*Dei congiamenti cui soggiacque l'idraulica condizione del Po*, etc., pp. 41, 42.

Del Noce states that in the levellings for the proposed Leopolda railway, he found that the bed of the Sieue had been permanently elevated two yards between 1708 and 1844, and that of the Fosso di San Gaudenzio more than a yard and a half between 1752 and 1845. These, indeed, are not rivers of the rank of the Po; but neither are they what are technically called torrents or mountain streams, whose flow is only an occasional effect of heavy rains or melting snow.—*Trattato delle Macchie e Foreste di Toscana*, Firenze, 1857, p. 29.

* The Noang-ho has repeatedly burst its dikes and changed the channel of its lower course, sometimes delivering its waters into the sea to the north, sometimes to the south of the peninsula of Chan-tung, thus varying its point of discharge by a distance of 220 miles.—Elisée Reclus, *La Terre*, t. i., p. 477.

See interesting notices of the lower course of the Noang-ho in *Nature*, Nov. 25, 1869.

The frequent changes of channel and mouth in the deltas of great rivers are by no means always an effect of diking. The mere accumulation of deposits in the beds of rivers which transport much sediment compels them continually to seek new outlets, and it is only by great effort that art can keep their points of discharge approximately constant. The common delta of the Ganges and the Brahmapootra is in a state of incessant change, and the latter river is said to have shifted its main channel 200 miles to the west since 1785, the revolution having been principally accomplished between 1810 and 1830.

when his ramparts have been, by his toil, raised to a certain height and widened to a certain thickness, she, by her laws of gravitation and cohesion, consolidates their material until it becomes almost as hard, as indissoluble, and as impervious as the rock.

But, though man may press the forces of nature into his service, there is a limit to the extent of his dominion over them, and unless future generations shall discover new modes of controlling those forces, or new remedies against their action, he must at last succumb in the struggle. When the marine estuaries and other basins of reception shall be filled up with the sedimentary débris of the mountains, or when the lower course of the rivers shall be raised or prolonged by their own deposits until they have, no longer, such a descent that gravitation and the momentum of the current can overcome the frictional resistance of the bed and banks, the water will, in spite of all obstacles, diffuse itself laterally and for a time raise the level of the champaign land upon its borders, and at last convert it into morasses. It is for this reason that Lombardini advises that a considerable space along the lower course of rivers be left undiked, and the water allowed to spread itself over its banks and gradually raise them by its deposits.* This would, indeed, be a palliative, but only a palliative. For the present, however, we have nothing better, and here, as often in political economy, we must content ourselves with "aprés nous le déluge," allowing posterity to suffer the penalty of our improvidence and our ignorance, or to devise means for itself to ward off the consequences of them.

The deposit of slime by rivers upon the flats along their banks not only contributes greatly to the fertility of the soil thus flowed, but it subserves a still more important purpose in the general economy of nature. All running streams begin with excavating channels for themselves, or deepening the natural depressions in which they flow;[*] but in proportion as their outlets are raised by the solid material transported by their currents, their velocity is diminished, they deposit gravel and sand at constantly higher and higher points, and so at last elevate, in the middle and lower part of their course, the beds they had previously scooped out.[†] The raising of the channels is compensated in part by the simultaneous elevation of their banks and the flats adjoining them, from the deposit of the finer particles of earth and vegetable mould brought down from the mountains, without which elevation the low grounds bordering all rivers would be, as in many cases they in fact are, mere morasses.

---

* This method has been adopted on the lower course of the Lamone, and a considerable extent of low ground adjacent to that river has been raised by spontaneous deposit to a sufficient height to admit of profitable cultivation.

---

[*] I do not mean to say that all rivers excavate their own valleys, for I have no doubt that in the majority of cases such depressions of the surface originate in higher geological causes, such as the fissures and other irregularities of surface which could not fail to accompany upheaval, and hence the valley makes the river, not the river the valley. But even if we suppose a basin of the hardest rock to be elevated at once, completely formed, from the submarine abyss where it was fashioned, the first shower of rain that falls upon it, after it rises to the air, will discharge its waters along the lowest lines of the surface, and cut those lines deeper, and so on with every successive rain. The disintegrated rock from the upper part of the basin forms the lower by alluvial deposit, which is constantly transported farther and farther until the resistance of gravitation and cohesion balances the mechanical force of the running water. Thus plains, more or less steeply inclined, are formed, in which the river is constantly changing its bed, according to the perpetually varying force and direction of its currents, modified as they are by ever-fluctuating conditions. Thus the Po is said to have long inclined to move its channel southwards, at certain points, in consequence of the mechanical force of its northern affluents. A diversion of these tributaries from their present beds, so that they should enter the main stream at other points and in different directions, might modify the whole course of that great river. But the mechanical force of the tributary is not the only element of its influence on the course of the principal stream. The deposits it lodges in the bed of the latter, acting as simple obstructions or causes of diversion, are not less important agents of change.

[†] The distance to which a new obstruction to the flow of a river, whether by a dam or by a deposit in its channel, will retard its current, or, in popular phrase, "set back the water," is a problem of more difficult practical solution than almost any other in hydraulics. The elements—such as straightness or crookedness of channel, character of bottom and banks, volume and previous velocity of current, mass of water far above the obstruction, extraordinary drought or humidity of seasons, relative extent to which the river may be affected by the precipitation in its own basin, and by supplies received through subterranean channels from sources so distant as to be exposed to very different meteorological influences, effects of clearing and other improvements always going on in new countries—are all extremely difficult, and some of them impossible, to be known and measured. In the American States, very numerous water-mills have been erected within a few years, and

All arrangements which tend to obstruct this process of raising the flats adjacent to the channel, whether consisting in dikes which confine the waters, and, at the same time, augment the velocity of the current, or in other means of producing the last-mentioned effect, interfere with the restorative economy of nature, and at last occasion the formation of marshes where, if left to herself, she might have accumulated inexhaustible stores of the richest soil, and spread them out in plains above the reach of ordinary floods.*

Dikes, which, as we have seen, are the means most frequently employed to prevent damage by inundation, are generally parallel to each other and separated by a distance not very much greater than the natural width of the bed.† If such walls are

---

there is scarcely a stream in the settled portion of the country which has not several mill-dams upon it. When a dam is raised—a process which the gradual diminution of the summer currents renders frequently necessary — or when a new dam is built, it often happens that the meadows above are flowed, or that the retardation of the stream extends back to the dam next above. This leads to frequent law-suits. From the great uncertainty of the facts, the testimony is more conflicting in these than in any other class of cases, and the obstinacy with which "water causes" are disputed has become proverbial.

[*] The sediment of the Po has filled up some lagoons and swamps in its delta, and converted them into comparatively dry land; but, on the other hand, the retardation of the current from the lengthening of its course, and the diminution of its velocity by the deposits at its mouth, have forced its waters at some higher points to spread in spite of embankments, and thus fertile fields have been turned into unhealthy and unproductive marshes.—See BOTTER, *Sulla condizione dei Terreni Maremmani nel Ferrarese. Annali di Agricoltura*, etc., Fasc. v., 1863.

[†] In the case of rivers flowing through wide alluvial plains and much inclined to shift their beds, like the Po, the embankments often leave a very wide space between them. The dikes of the Po are sometimes three or four miles apart.

high enough to confine the water and strong enough to resist its pressure, they secure the lands behind them from all the evils of inundation except those resulting from filtration; but such ramparts are enormously costly in original construction and in maintenance, and, as has been already shown, the filling up of the bed of the river in its lower course, by sand and gravel, often involves the necessity of incurring new expenditures in increasing the height of the banks.* They are

---

* It appears from the investigations of Lombardini that the rate of elevation of the bed of the Po has been much exaggerated by earlier writers, and in some parts of its course the change is so slow that its level may be regarded as nearly constant. Observation has established a similar constancy in the bed of the Rhone and of many other important rivers, while, on the other hand, the beds of the Adige and the Brenta, streams of a more torrential character, are raised considerably above the level of the adjacent fields.

The length of the lower course of the Po having been considerably increased by the filling up of the Adriatic with its deposits, the velocity of the current ought, *prima facie*, to have been diminished and its bed raised in proportion. There are abundant grounds for believing that this has happened in the case of the Nile, and one reason why the same effect has not been more sensibly perceptible in the Po is, that the confinement of the current by continuous embankments gives it a high-water velocity sufficient to sweep out deposits let fall at lower stages and slower movements of the water. Torrential streams tend to excavate or to raise their beds according to the inclination, and to the character of the material they transport. No general law on this point can be laid down in relation to the middle and lower courses of rivers. The conditions which determine the question of the depression or elevation of a river-bed are too multifarious, variable, and complex, to be subjected to formulæ, and they can scarcely even be enumerated.

The following observation, however, though apparently too unconditionally stated, is too important to be omitted.

Rivers which transport sand, gravel, pebbles, heavy mineral matter in short, tend to raise their own beds; those charged only with fine, light earth, to cut them deeper. The prairie rivers of the western United States have deep channels, because the mineral matter they carry down is not heavy enough to resist the impulse of even a moderate current, and those tributaries of the Po which deposit their sediment in the lakes—the Ticino, the Adda, the Oglio, and the Mincio—flow in deep cuts, for the same reason.—BAUMGARTEN, p. 132.

In regard to the level of the bed of the Po, there is another weighty consideration which does not seem to have received the attention it deserves. I attended, too, with some collateral disadvantages. They deprive the earth of the fertilizing deposits of the waters, which are powerful natural restoratives of soils exhausted by cultivation; they accelerate the rapidity and transporting power of the current at high water by confining it to a narrower channel, and it consequently conveys to the sea the earthy matter it holds in suspension, and chokes up harbors with a deposit which it would otherwise have spread over a wider surface; they interfere with roads and the convenience of river navigation, and no amount of cost or care can secure them from occasional rupture, in case of which the rush of the waters through the breach is more destructive than the natural flow of the highest inundation.*

For these reasons, many experienced engineers are of opinion

---

refer to the secular depression of the western coast of the Adriatic, which is computed at the rate of fifteen or twenty centimètres in a century, and which of course increases the inclination of the bed, and the velocity and transporting power of the current of the Po, *unless* we assume that the whole course of the river, from the sea to its sources, shares in the depression. Of this assumption there is no proof, and the probability is to the contrary. For the evidence, though not conclusive, perhaps, tends to show an elevation of the Tuscan coast, and even of the Ligurian shore at points lying farther west than the sources of the Po. The level of certain parts of the bed of the river referred to by Lombardini as constant, is not their elevation as compared with points nearer the sea, but relatively to the adjacent plains, and there is every reason to believe that the depression of the Adriatic coast, whether, as is conceivable, occasioned by the mere weight of the fluviatile deposits or by more general geological causes, has increased the slope of the bed of the river between the points in question and the sea. In this instance, then, the relative permanency of the river level at certain points may be, not the ordinary case of a natural equilibrium, but the negative effect of an increased velocity of current which prevents deposits where they would otherwise have happened.

* To secure the city of Sacramento, in California, from the inundations to which it is subject, a dike or levée was built upon the bank of the river and raised to an elevation above that of the highest known floods, and it was connected, below the town, with grounds lying considerably above the river. On one occasion a breach in the dike occurred above the town at a very high stage of the flood. The water poured in behind it, and overflowed the lower part of the city, which remained submerged for some time after the river had

that the system of longitudinal dikes is fundamentally wrong, and it has been argued that if the Po, the Adige, and the Brenta had been left unconfined, as the Nile formerly was, and allowed to spread their muddy waters at will, according to the laws of nature, the sediment they have carried to the coast would have been chiefly distributed over the plains of Lombardy. Their banks, it is supposed, would have risen as fast as their beds, the coast-line would not have been extended so far into the Adriatic, and, the current of the streams being consequently shorter, the inclination of their channel and the rapidity of their flow would not have been so greatly diminished. Had

---

retired to its ordinary level, because the dike, which had been built to keep the water *out*, now kept it *in*.

According to Arthur Young, on the lower Po, where the surface of the river at high water has been elevated considerably above the level of the adjacent fields by diking, the peasants in his time frequently endeavored to secure their grounds against threatened devastation through the bursting of the dikes, by crossing the river when the danger became imminent and opening a cut in the opposite bank, thus saving their own property by flooding their neighbors'. He adds, that at high water the navigation of the river was absolutely interdicted, except to mail and passenger boats, and that the guards fired upon all others; the object of the prohibition being to prevent the peasants from resorting to this measure of self-defence.—*Travels in Italy and Spain*, Nov. 7, 1789.

In a flood of the Po in 1839, a breach of the embankment took place at Bonizzo. The water poured through and inundated 116,000 acres, or 181 square miles, of the plain to the depth of from twenty to twenty-three feet, in the lower parts. The inundation of May, 1872, a great breach occurred in the dike near Ferrara, and 170,000 acres of cultivated land were overflowed, and a population of 30,000 souls driven from their homes. In the flood of October in the same year, in consequence of a breach of the dike at Revere, 250,000 acres of cultivated soil were overflowed, and 60,000 persons were made homeless. The dikes were seriously injured at more than forty points. See page 279, *ante*. In the flood of 1856, the Loire made seventy-three breaches in its dikes, and thus, instead of a comparatively gradual rise and gentle expansion of its waters, it created seventy-three impetuous torrents, which inflicted infinitely greater mischief than a simply natural overflow would have done. The dikes or *levées* of the Mississippi, being of more recent construction than those of the Po, are not yet well consolidated and fortified, and for this reason crevasses which occasion destructive inundations are of very frequent occurrence.

man, too, spared a reasonable proportion of the forests of the Alps, and not attempted to control the natural drainage of the surface, the Po, it has been said, would resemble the Nile in all its essential characteristics, and, in spite of the difference of climate, perhaps be regarded as the friend and ally, not the enemy and the invader, of the population which dwells upon its banks.

But it has been shown by Humphreys and Abbot that the system of longitudinal dikes is the only one susceptible of advantageous application to the Mississippi, and if we knew the primitive geography and hydrography of the basin of the Po as well as we do those of the valley of the great American river, we should very probably find that the condemnation of the plan pursued by the ancient inhabitants of Lombardy is a too hasty generalization, and that the case of the Nile is an exception, not an example of the normal régime and condition of a great river.*

But in any event, these theoretical objections are counsels *après coup*. The dikes of the Po and probably of some of its tributaries were begun before we have any trustworthy physical or political annals of the provinces they water. The civilization of the valley has accommodated itself to these arrangements, and the interests which might be sacrificed by a change of system are too vast to be hazarded by what, in the present state of our knowledge, can be only considered as a doubtful experiment.*

---

* Embankments have been employed on the lower course of the Po for at least two thousand years, and for some centuries they have been connected in a continuous chain from the sea to the vicinity of Cremona. From early ages the Italian hydrographers have stood in the front rank of their profession, and the Italian literature of this branch of material improvement is exceedingly voluminous, exhaustive, and complete.

"The science of rivers after the barbarous ages," says Mengotti, "may be said to have been born and perfected in Italy." The eminent Italian engineer Lombardini published in 1870, under the title of *Guida allo studio dell' idrologia fluviale e dell' Idraulica pratica*, which serves both as a summary of the recent progress of that science and as an index to the literature of the subject. The professional student, therefore, as well as the geographer, will have very frequent occasion to consult Italian authorities, and in the very valuable Report of Humphreys and Abbot on the Mississippi, America has lately made a contribution to our potamological knowledge, which, in scientific interest and practical utility, does not fall short of the ablest European productions in the same branch of inquiry.

The embankments of the Po, though they are of vast extent and have employed centuries in their construction, are inferior in magnitude to the dikes or levées of the Mississippi, which are the work of scarcely a hundred years, and of a comparatively sparse population. On the right or western bank of the river, the levée extends, with only occasional interruptions from high bluffs and the mouths of rivers, for a distance of more than eleven hundred miles. The left bank is, in general, higher than the right, and upon that side a continuous embankment is not needed; but the total length of the dikes of the Mississippi, including those of the lower course of its tributaries and of its *bayous* or natural emissaries, is not less than 2,500 miles. They constitute, therefore, not only one of the greatest material achievements of the American people, but one of the most remarkable systems of physical improvement which has been anywhere accomplished in modern times.

Those who condemn the system of longitudinal embankments have often advised that, in cases where that system cannot be abandoned without involving too great a sacrifice of existing interests, the elevation of the dikes should be much reduced, so as to present no obstruction to the lateral spread of extraordinary floods, and that they should be provided with sluices to admit the water without violence whenever they are likely to be overflowed. Where dikes have not been erected, or where they have been reduced in height, it is proposed to construct, at convenient intervals, transverse embankments of moderate height running from the banks of the river across the plains to the hills which bound them. These measures, it is argued, will diminish the violence of inundations by permitting the waters to extend themselves over a greater surface, and by thus retarding the flow of the river currents, will, at the same time, secure the deposit of fertilizing slime upon all the soil covered by the flood.*

---

* Dupenchel advised a resort to the "heroic remedy" of sacrificing, or converting into cellars, the lower storeys of houses in cities exposed to river inundation, filling up the streets, and admitting the water of floods freely over the adjacent country, and thus allowing it to raise the level of the soil to that of the highest inundations.—*Traité d'Hydraulique et de Géologie Agricoles.* Paris, 1868, p. 241.

Rozet, an eminent French engineer, has proposed a method of diminishing the ravages of inundations, which aims to combine the advantages of all other systems, and at the same time to obviate the objections to which they are all more or less liable.† The plan of Rozet is recommended by its simplicity and cheapness as well as its facility and rapidity of execution, and is looked upon with favor by many persons very competent to judge in such matters. It is, however, by no means capable of universal application, though it would often doubtless prove highly useful in connection with the measures now employed in South-eastern France. He proposes to commence with the amphitheatres in which mountain torrents so often rise, by covering their slopes and filling their beds with loose blocks of rock, and by constructing at their outlets, and at other narrow points in the channels of the torrents, permeable barriers of the same material promiscuously heaped up, much according to the method employed by the ancient Romans in their northern provinces for a similar purpose. By this means, he supposes, the rapidity of the current would be checked, and the quantity of transported pebbles and gravel—which, by increasing the mechanical force of the water, greatly aggravate the damage by floods—much diminished. When the stream has reached that part of its course where it is bordered by soil capable of cultivation, and worth the expense of protection, he proposes to place along one or both banks, according to circumstances, a line of cubical blocks of stone or pillars of masonry three or four feet high and wide, and at the distance of about eleven yards from each other. The space between the two lines, or between a line and the opposite high bank, would, of course, be determined by observation of the width of the swift-water current at high floods. As an auxiliary measure, small ditches and banks, or low walls of pebbles, should be constructed from the line of blocks across the grounds to be protected, nearly at right angles to the current, but slightly inclining downwards, and at convenient distances from each other. Rozet thinks the proper interval would be 300 yards, and it is evident that, if he is right in his main principle, hedges, rows of trees, or even common fences, would in many cases answer as good a purpose as banks and trenches or low walls. The blocks or pillars of stone would, he contends, check the lateral currents so as to compel them to let fall all their pebbles and gravel in the main channel—where they would be rolled along until ground down to sand or silt—and the transverse obstructions would detain the water upon the soil long enough to secure the deposit of its fertilizing slime. Numerous facts are cited in support of the author's views, and I imagine there are few residents of rural districts whose own observation will not furnish testimony confirmatory of their soundness.*

---

* The system described in the text is substantially the Egyptian method, the ancient Nile dikes having been constructed rather to retain than to exclude the water.

† *Moyens de forcer les Torrents de rendre une partie du sol qu'ils ravagent, et d'empêcher les grandes Inondations.*

---

* The effect of trees and other detached obstructions in checking the flow of water is particularly noticed by Palissy in his essay on *Waters and Fountains*, p. 173, edition of 1844. "There be," says he, "in divers parts of France, and specially at Nantes, wooden bridges, where, to break the force of the waters and of the floating ice, which might endamage the piers of the said bridges, they have driven upright timbers into the bed of the rivers above the said piers, without the which they should abide but little. And in likewise, the trees which be planted along the mountains do much deaden the violence of the waters that flow from them."

Lombardini attaches great importance to the planting of rows of trees transversely to the current on grounds subject to overflow.—*Esame degli Studi sul Tevere*, § 53, and *Appendice*, §§ 33, 34.

Removal of Obstructions.

The removal of obstructions in the beds of rivers by dredging the bottom or blasting rocks, the washing out of deposits and locally increasing the depth of water by narrowing the channel by means of spurs or other constructions projecting from the banks, and, finally, the cutting off of bends and thus shortening the course of the stream, diminishing the resistance of its shores and bottom and giving the bed a more rapid declivity, have all been employed not only to facilitate navigation, but as auxiliaries to more effectual modes of preventing inundations. But a bar removed from one point is almost sure to re-form at the same or another, spurs occasion injurious eddies and unforeseen diversions of the current,* and the cutting off of bends, though occasionally effected by nature herself, and sometimes advantageous in torrential streams whose banks are secured by solid walls of stone or other artificial constructions, seldom establishes a permanent channel, and besides, the increased rapidity of the flow through the new cut often injuriously affects the régime of the river for a considerable distance below.†

---

* The introduction of a new system of spurs with parabolic curves has been attended with great advantage in France.—*Annales du Gênie Civil*, Mai, 1863.

† This practice has sometimes been resorted to on the Mississippi with advantage to navigation, but it is quite another question whether that advantage has not been too dearly purchased by the injury to the banks at lower points. If we suppose a river to have a navigable course of 1,600 miles as measured by its natural channel, with a descent of 800 feet, we shall have a fall of six inches to the mile. If the length of channel be reduced to 1,200 miles by cutting off bends, the fall is increased to eight inches per mile. The augmentation of velocity consequent upon this increase of inclination is not computable without taking into account other elements, such as depth and volume of water, diminution of direct resistance, and the like, but in almost any supposable case, it would be sufficient to produce great effects on the height of floods, the deposit of sediment in the channel, on the shores, and at the outlet, the erosion of banks and other points of much geographical importance.

The Po, in those parts of its course where the embankments leave a wide space between, often cuts off bends in its channel and straightens its course.

Combination of Methods.

Upon the whole, it is obvious that no one of the methods heretofore practised or proposed for averting the evils resulting from river inundations is capable of universal application. Each of them is specially suited to a special case. But the hydrography of almost every considerable river and its tributaries will be found to embrace most special cases, most known forms of superficial fluid circulation. For rivers, in general, begin in the mountains, traverse the plains, and end in the sea; they are torrents at their sources, swelling streams in their middle course, placid currents, flowing *molli flumine*, at their termination. Hence in the different parts of their course the different methods of controlling and utilizing them may successively find application, and there is every reason to believe that by a judicious application of all, every great river may, in a considerable degree, be deprived of its powers of evil and rendered subservient to the use, the convenience, and the dominion of man.*

These short cuts are called *salti*, or leaps, and sometimes abridge the distance between their termini by several miles. In 1777, the salto of Cottaro shortened a distance of 7,000 mètres by 5,000, or, in other words, reduced the length of the river by five kilomètres, or about three miles, and in 1807 and 1810 the two *salti* of Mezzanone effected a still greater reduction.

* On the remedies against inundation, see the valuable paper of LOMBARDINI, *Sulle Inondazioni avvenute in questi ultimi tempi in Francia*. Milano, 1858.

There can be no doubt that in the case of rivers which receive their supply in a large measure from mountain streams, the methods described in a former chapter as recently employed in South-eastern France to arrest the formation and lessen the force of torrents, would prove equally useful as a preventive remedy against inundations. They would both retard the delivery of surface-water and diminish the discharge of sediment into rivers, thus operating at once against the two most efficient causes of destructive floods. See Chapter III., pp. 316 *et seqq.*

Dikes of the Nile.

"History tells us," says Mengotti, "that the Nile became terrible and destructive to ancient Egypt, in consequence of being confined within elevated dikes, from the borders of Nubia to the sea. It being impossible for these barriers to resist the pressure of its waters at such a height, its floods burst its ramparts, sometimes on one side, sometimes on the other, and deluged the plains, which lay far below the level of its current. . . . In one of its formidable inundations the Nile overwhelmed and drowned a large part of the population. The Egyptians then perceived that they were struggling against nature in vain, and they resolved to remove the dikes, and permit the river to expand itself laterally and raise by its deposits the surface of the fields which border its channel."*

The original texts of the passages cited by Mengotti, from Latin translations of Diodorus Siculus and Plutarch and from Pliny the Elder, do not by any means confirm this statement, though the most important of them, that from Diodorus Siculus, is, perhaps, not irreconcilable with it. Not one of them speaks of the removal of the dikes, and I understand them all as relating to the mixed system of embankments, reservoirs, and canals which have been employed in Egypt through the whole period concerning which we have clear information. I suppose that the disastrous inundations referred to by the authors in question were simply extraordinary floods of the same character as those which have been frequent at later periods of Egyptian history, and I find nothing in support of the proposition that continuous embankments along the banks of the Nile ever existed until such were constructed by Mehemet Ali.†

---

* *Idraulica Fisica e Sperimentale.* 2d edizione, vol. i., pp. 131, 133.

† The gradual elevation of the bed of the Nile from sedimentary deposit, from the prolongation of the Delta and consequent reduction of the inclination of the river-bed, or, as has been supposed by some, though without probability,

The object of the dikes of the Po, and, with few exceptions, of those of other European rivers, has always been to confine the waters of floods and the solid material transported by them within as narrow a channel as possible, and entirely to prevent them from flowing over the adjacent plains. The object of the Egyptian dikes and canals is the reverse, namely, to diffuse the swelling waters and their sediment over as wide a surface as possible, to store them up until the soil they cover has been thoroughly saturated and enriched, and then to conduct them over other grounds requiring a longer or a second submersion, and, in general, to suffer none of the precious fluid to escape except by evaporation and infiltration.

Lake Moeris, whether wholly an artificial excavation, or a natural basin converted by embankments into a reservoir, was designed chiefly for the same purpose as the *barrage* built by Mougel Bey across the two great arms which enclose the Delta, namely, as a magazine to furnish a perennial supply of water to the thirsty soil. But these artificial arrangements alone did not suffice. Canals were dug to receive the water at lower stages of the river and conduct it far into the interior, and as all this was still not enough, hundreds of thousands of wells were sunk to bring up from the subsoil, and spread over the surface, the water which, by means of infiltration from the river-bed, pervades the inferior strata of the whole valley.[*]

If a system of lofty continuous dikes, like those of the Po, had really been adopted in Egypt, in the early dynasties when the power and the will to undertake the most stupendous material enterprises were so eminently characteristic of the gov-

---

from a secular rise of the coast, rendered necessary some change in the hydraulic arrangements of Egypt. Mehemet Ali was advised to adopt a system of longitudinal levées, and he embanked the river from Jebel Silsileh to the sea with dikes six or seven feet high and twenty feet thick. Similar embankments were made around the Delta. These dikes are provided with transverse embankments, with sluices for admitting and canals for distributing the water, and they serve rather to retain the water and control its flow than to exclude it.—CLOT BEY, *Aperçu sur l'Egypte*, ii., 437.

[*] It is said that in the Delta alone 50,000 wells are employed for irrigation.

ernment of that country, and persevered in through later ages, and the waters of the annual inundation had thus been permanently prevented from flooding the land, it is conceivable that the productiveness of the small area of cultivable soil in the Nile valley might have been long kept up by artificial irrigation and the application of manures. But nature would have rebelled at last, and centuries before our time the mighty river would have burst the fetters by which impotent man had vainly striven to bind his swelling floods, the fertile fields of Egypt would have been converted into dank morasses, and then, perhaps, in some distant future, when the expulsion of man should have allowed the gradual restoration of the primitive equilibrium, would be again transformed into luxuriant garden and plough land. Fortunately, the *sapientia Ægyptiorum*, the wisdom of the Egyptians, taught them better things. They invited and welcomed, not repulsed, the slimy embraces of Nilus, and his favors have been, from the hoariest antiquity, the greatest material blessing that nature ever bestowed upon a people.*

Deposits of the Nile.

The Nile is larger than all the rivers of Lombardy together,† it drains a basin fifty, possibly even a hundred, times as extensive, its banks have been occupied by man probably twice as long. But its geographical character has not been much changed in the whole period of recorded history, and, though

---

* Deep borings have not detected any essential difference in the quantity or quality of the deposits of the Nile for forty or fifty, or, as some compute, for a hundred centuries. From what vast store of rich earth does this river derive the three or four inches of fertilizing material which it spreads over the soil of Egypt every hundred years? Not from the White Nile, for that river drops nearly all its suspended matter in the broad expansions and slow current of its channel south of the tenth degree of north latitude. Nor does it appear that much sediment is contributed by the Bahr-el-Azrek, which flows through forests for a great part of its course. I have been informed by an old European resident of Egypt who is very familiar with the Upper Nile, that almost the whole of the earth with which its waters are charged is brought down by the Takazzé.

† From daily measurements during a period of fourteen years—1827 to 1840—the mean delivery of the Po at Ponte Lagoscuro, below the entrance of its last tributary, is found to be 1,720 cubic mètres, or 60,745 cubic feet,

---

per second. Its smallest delivery is 186 cubic mètres, or 6,569 cubic feet, its greatest 5,156 cubic mètres, or 152,094 cubic feet. The average delivery of the Nile being 101,000 cubic feet per second, it follows that the Po contributes to the Adriatic rather more than six-tenths as much water as the Nile to the Mediterranean—a result which will surprise most readers.

It is worth remembering that the mean delivery of the Rhone is almost identical with that of the Po, and that of the Rhine is very nearly the same. Though the Po receives four-tenths of its water from lakes, in which the streams that empty into them let fall the solid material they bring down from the mountains, its deposits in the Adriatic are at least sixty or seventy per cent. greater than those transported to the Mediterranean by the Rhone, which derives most of its supply from mountain and torrential tributaries. Those tributaries lodge much sediment in the Lake of Geneva and the Lac de Bourget, but the total erosion of the Po and its affluents must be considerably greater than that of the Rhone system. The Rhine conveys to the sea much less sediment than either of the other two rivers.—LOMBARDINI, *Cargiamenti nella condizione del Po*, pp. 29, 39.

The mean discharge of the Mississippi is 675,000 cubic feet per second, and, accordingly, that river contributes to the sea about eleven times as much water as the Po, and more than six and a half times as much as the Nile. The discharge of the Mississippi is estimated at one-fourth of the precipitation in its basin—certainly a very large proportion, when we consider the rapidity of evaporation in many parts of the basin, and the probable loss by infiltration. —HUMPHREYS AND ABBOT'S *Report*, p. 93.

The basin of the Mississippi has an area forty-six times as large as that of the Po, with a mean annual precipitation of thirty inches, while that of the Po, at least according to official statistics, has a precipitation of forty inches. Hence the down-fall in the former is one-fourth less than in the latter. Besides this, the Mississippi loses little or nothing by the diversion of its waters for irrigation. Consequently the measured discharge of the Mississippi is proportionally much less than that of the Po, and we are authorized to conclude that the difference is partly due to the escape of water from the bed, or at least the basin of the Mississippi, by subterranean channels.

These comparisons are interesting in reference to the supply received by the sea directly from great rivers, but they fail to give a true idea of the real volume of the latter. To take the case of the Nile and the Po: we have reason to suppose that comparatively little water is diverted from the tributaries of the former for irrigation, but enormous quantities are drawn from its main trunk for that purpose, below the point where it receives its last affluent. This quantity is now increasing in so rapid a proportion, that Elisée Reclus its outlets have somewhat fluctuated in number and position, its historically known encroachments upon the sea are trifling compared with those of the Po and the neighboring streams. The deposits of the Nile are naturally greater in Upper than in Lower Egypt. They are found to have raised the soil at Thebes about seven feet within the last seventeen hundred years, and in the Delta the rise has been certainly more than half as great.

We shall, therefore, probably not exceed the truth if we suppose the annually inundated surface of Egypt to have been elevated, upon an average, ten feet,* within the last 5,000 years,

---

foresees the day when the entire low-water current will be absorbed by new arrangements to meet the needs of extended and improved agriculture. On the other hand, while the affluents of the Po send off a great quantity of water into canals of irrigation, the main trunk loses little or nothing in that way except at Chivasso. Trustworthy data are wanting to enable us to estimate how far these different modes of utilizing the water balance each other in the case under consideration. Perhaps the Canal Cavour, and other irrigating canals now proposed, may one day intercept as large a proportion of the supply of the lower Po as Egyptian dikes, canals, shadoofs, and steam-pumps do of that of the Nile.

Another circumstance is important to be considered in comparing the character of these three rivers, The Po runs nearly east and west, and it and its tributaries are exposed to no other difference of meteorological conditions than those which always subsist between the mountains and the plains. The course of the Nile and the Mississippi is mainly north and south. The sources of the Nile are in a very humid region, its lower course for many hundred miles in almost rainless latitudes with enormous evaporating power, while the precipitation is large throughout the Mississippi system, except in the basins of some of its western affluents.

* Fraas and Eyth maintain that we have no trustworthy data for calculating the annual or secular elevation of the soil of Egypt by the sediment of the Nile. The deposit, they say, is variable from irregularity of current, and especially from the interference of man with the operations of nature, to a degree which renders any probable computation of the amount quite impossible. —FRAAS, *Aus dem Orient*, pp. 212, 213.

The sedimentary matter transported by the Nile might doubtless be estimated with approximate precision by careful observation of the proportion of suspended slime and water at different stations and seasons for a few successive years. Figari Bey states that at low stages the water of the Nile contains little or no sediment, and that the greatest proportion occurs about the end of or twice and a half the period during which the history of the Po is known to us.*

As I have observed, the area of cultivated soil is much less extensive now than under the dynasties of the Pharaohs and the Ptolemies; for—though, in consequence of the elevation of the river-bed, the inundations now have a wider *natural* spread—the industry of the ancient Egyptians conducted the Nile water over a great surface which it does not now reach.

Had the Nile been banked in, like the Po, all this deposit, except that contained in the water diverted by canals or otherwise drawn from the river for irrigation and other purposes,

---

July, and, of course, while the river is still rising. Experiments at Khartum at that season showed solid matter in the proportion of one to a thousand by weight. The quantity is relatively greater at Cairo, a fact which shows that the river receives more earth from the erosion of its banks than it deposits at its own bottom, and it must consequently widen its channel unless we suppose a secular depression of the coast at the mouth of the Nile which produces an increased inclination of the bed of the river, and consequently an augmented velocity of flow sufficient to sweep out earth from the bottom and mix it with the current.

Herschell states the Nile sediment at 1 in 633 by weight, and computes the entire annual quantity at 140 millions of tons.—*Physical Geography*, p. 231.

The mean proportion of sedimentary material in the waters of the Mississippi is calculated at 1 to 1,500 by weight, and 1 to 2,900 in volume, and the total annual quantity at 812,500,000,000 pounds, which would cover one square mile to the depth of 241 feet.—HUMPHREYS AND ABBOT, *Report*, p. 149.

* We are quite safe in supposing that the valley of the Nile has been occupied by man at least 5,000 years. The dates of Egyptian chronology are uncertain, but I believe no inquirer estimates the age of the great pyramids at less than forty centuries, and the construction of such works implies an already ancient civilization.

It is an interesting fact that the old Egyptian system of embankments and canals is probably more ancient than the geological changes which have converted the Mississippi from a limpid to a turbid stream, and occasioned the formation of the vast delta at the mouth of that river. Humphreys and Abbot conclude that the delta of the Mississippi began its encroachments on the Gulf of Mexico not more than 4,400 years ago, before which period they suppose the Mississippi to have been "a comparatively clear stream," conveying very little sediment to the sea. The present rate of advance of the delta is 262 feet a year, and there are reasons for thinking that the amount of deposit has long been approximately constant.—*Report*, pp. 435, 436.

would have been carried out to sea. This would have been a considerable quantity; for the Nile holds some earth in suspension at all seasons except at the very lowest water, a much larger proportion during the flood, and irrigation must have been carried on during the whole year. The precise amount of sediment which would have been thus distributed over the soil is matter of conjecture, but though large, it would have been much less than the inundations have deposited, and continuous longitudinal embankments would have compelled the Nile to transport to the Mediterranean an immense quantity over and above what it has actually deposited in that sea. The Mediterranean is shoal for some miles out to sea along the whole coast of the Delta, and the large bays or lagoons within the coast-line, which communicate both with the river and the sea, have little depth of water. These lagoons the river deposits would have filled up, and there would still have been surplus earth enough to extend the Delta far into the Mediterranean.*

Obstruction of River Mouths.

The mouths of a large proportion of the streams known to ancient navigation are already blocked up by sand-bars or fluviatile deposits, and the maritime approaches to river harbors frequented by the ships of Phenicia and Carthage and Greece and Rome are shoaled to a considerable distance out to sea. The inclination of the lower course of almost every known river-bed has been considerably reduced within the historical period, and nothing but great volume of water, or exceptional rapidity of flow, now enables a few large streams like the Amazon, the La Plata, the Ganges, and, in a less degree, the Mississippi, to carry their own deposits far enough out into deep water to prevent the formation of serious obstructions to navigation. But the degradation of their banks, and the transportation of earthy matter to the sea by their currents, are gradually filling up the estuaries even of these mighty floods, and unless the threatened evil shall be averted by the action of geological forces, or by artificial contrivances more efficient than dredging-machines, the destruction of every harbor in the world which receives a considerable river must inevitably take place at no very distant date.

---

* The present annual extension of the Delta is, if perceptible, at all events very small. According to some authorities, a few hectares are added every year at each Nile mouth. Others, among whom I may mention Fraas, deny that there is any extension at all, the deposit being balanced by a secular depression of the coast.

Elisée Reclus states that the Delta advances about 40 inches per year.—*La Terre*, i., p. 500.

This result would, perhaps, have followed in some incalculably distant future, if man had not come to inhabit the earth as soon as the natural forces which had formed its surface had arrived at such an approximate equilibrium that his existence on the globe was possible; but the general effect of his industrial operations has been to accelerate it immensely. Rivers, in countries planted by nature with forests and never inhabited by man, employ the little earth and gravel they transport chiefly to raise their own beds and to form plains in their basins. In their upper course, where the current is swiftest, they are most heavily charged with coarse rolled or suspended matter, and this, in floods, they deposit on their shores in the mountain valleys where they rise; in their middle course, a lighter earth is spread over the bottom of their widening basins, and forms plains of moderate extent; the fine silt which floats farther is deposited over a still broader area, or, if carried out to sea, is in great part quickly swept far off by marine currents and dropped at last in deep water. Man's "improvement" of the soil increases the erosion from its surface; his arrangements for confining the lateral spread of the water in floods compel the rivers to transport to their mouths the earth derived from that erosion even in their upper course; and, consequently, the sediment they deposit at their outlets is not only much larger in quantity, but composed of heavier materials, which sink more readily to the bottom of the sea and are less easily removed by marine currents.

The tidal movement of the ocean, deep-sea currents, and the agitation of inland waters by the wind, lift up the sands strewn over the bottom by diluvial streams or sent down by mountain torrents, and throw them up on dry land, or deposit them in sheltered bays and nooks of the coast—for the flowing is stronger than the ebbing tide, the affluent than the refluent wave. This cause of injury to harbors it is not in man's power to resist by any means at present available; but, as we have seen, something can be done to prevent the degradation of high grounds, and to diminish the quantity of earth which is annually abstracted from the mountains, from table-lands, and from river-banks, to raise the bottom of the sea.

This latter cause of harbor obstruction, though an active agent, is, nevertheless, in many cases, the less powerful of the two. The earth suspended in the lower course of fluviatile currents is lighter than sea-sand, river water lighter than sea water, and hence, if a land stream enters the sea with a considerable volume, its water flows over that of the sea, and bears its slime with it until it lets it fall far from shore, or, as is more frequently the case, mingles with some marine current and transports its sediment to a remote point of deposit. The earth borne out of the mouths of the Nile is in part carried over the waves which throw up sea-sand on the beach, and deposited in deep water, in part drifted by the current, which sweeps east and north along the coasts of Egypt and Syria, and lodged in every nook along the shore—and among others, to the great detriment of the Suez Canal, in the artificial harbor at its northern terminus—and in part borne along until it finds a final resting-place in the north-eastern angle of the Mediterranean.* Thus the earth loosened by the rude Abyssinian ploughshare, and washed down by the rain from the hills of Ethiopia which man has stripped of their protecting forests, contributes to raise the plains of Egypt, to shoal the maritime channels which lead to the city built by Alexander near the mouth of the Nile, to obstruct the artificial communication between the Mediterranean and the Red Sea, and to fill up the harbors made famous by Phenician commerce.

---

* "The stream carries this mud, etc., at first farther to the east, and only lets it fall where the force of the current becomes weakened. This explains the continual advance of the land seaward along the Syrian coast, in consequence of which Tyre and Sidon no longer lie on the shore, but some distance inland. That the Nile contributes to this deposit may easily be seen, even by the unscientific observer, from the stained and turbid character of the water

Deposits of the Tuscan Rivers.

The Arno, and all the rivers rising on the western slopes and spurs of the Apennines, carry down immense quantities of mud to the Mediterranean. There can be no doubt that the volume of earth so transported is very much greater than it would have been had the soil about the headwaters of those rivers continued to be protected from wash by forests; and there is as little question that the quantity borne out to sea by the rivers of Western Italy is much increased by artificial embankments, because they are thereby prevented from spreading over the surface the sedimentary matter with which they are

---

for many miles from its mouths. Ships often encounter floating masses of Nile mud, and Dr. Clarke thus describes a case of this sort:

"While we were at table, we heard the sailors who were throwing the lead suddenly cry out: 'Three and a half!' The ship slackened her way, and veered about. As she came round, the whole surface of the water was seen to be covered with thick, black mud, which extended so far that it appeared like an island. At the same time, actual land was nowhere to be seen—not even from the mast-head—nor was any notice of such a shoal to be found on any chart on board. The fact is, as we learned afterwards, that a stratum of mud, stretching from the mouths of the Nile for many miles out into the open sea, forms a movable deposit along the Egyptian coast. If this deposit is driven forwards by powerful currents, it sometimes rises to the surface, and disturbs the mariner by the sudden appearance of shoals where the charts lead him to expect a considerable depth of water. But these strata of mud are, in reality, not in the least dangerous. As soon as a ship strikes them they break up at once, and a frigate may hold her course in perfect safety where an inexperienced pilot, misled by his soundings, would every moment expect to be stranded."—BÖTTGER, *Das Mittelmeer*, pp. 188, 189.

This phenomenon is not peculiar to the locality in question, and it is frequently observed in the Gulf of Bengal, and other great marine estuaries.

charged. The western coast of Tuscany has advanced some miles seawards within a very few centuries. The bed of the sea, for a long distance, has been raised, and of course the relative elevation of the land above it lessened; harbors have been filled up and destroyed; long lines of coast dunes have been formed, and the diminished inclination of the beds of the rivers near their outlets has caused their waters to overflow their banks and convert them into pestilential marshes. The territorial extent of Western Italy has thus been considerably increased, but the amount of soil habitable and cultivable by man has been, in a still higher proportion, diminished. The coast of ancient Etruria was filled with great commercial towns, and their rural environs were occupied by a large and prosperous population. But maritime Tuscany has long been one of the most unhealthy districts in Christendom; the famous Etruscan mart of Populonia has scarcely an inhabitant; the coast is almost absolutely depopulated, and the malarious fevers have extended their ravages far into the interior.

These results are certainly not to be ascribed wholly to human action. They are, in a large proportion, due to geological causes over which man has no control. The soil of much of Tuscany becomes pasty, almost fluid even, as soon as it is moistened, and when thoroughly saturated with water, it flows like a river. Such a soil as this would not be completely protected by woods, and, indeed, it would now be difficult to confine it long enough to allow it to cover itself with forest vegetation. Nevertheless, it certainly was once chiefly wooded, and the rivers which flow through it must then have been much less charged with earthy matter than at present, and they must have carried into the sea a smaller proportion of their sediment when they were free to deposit it on their banks than since they have been confined by dikes.

It is, in general, true, that the intervention of man has hitherto seemed to insure the final exhaustion, ruin, and desolation of every province of nature which he has reduced to his dominion. Attila was only giving an energetic and picturesque expression to the tendencies of human action, as personified in himself, when he said that "no grass grew where his horse's hoofs had trod." The instances are few, where a second civilization has flourished upon the ruins of an ancient culture, and lands once rendered uninhabitable by human acts or neglect have generally been forever abandoned as hopelessly irreclaimable. It is, as I have before remarked, a question of vast importance, how far it is practicable to restore the garden we have wasted, and it is a problem on which experience throws little light, because few deliberate attempts have yet been made at the work of physical regeneration, on a scale large enough to warrant general conclusions in any one class of cases.

The valleys and shores of Tuscany form, however, a striking exception to this remark. The success with which human guidance has made the operations of nature herself available for the restoration of her disturbed harmonies, in the Val di Chiana and the Tuscan Maremma, is among the noblest, if not the most brilliant achievements of modern engineering, and, regarded in all its bearings on the great question of which I have just spoken, it is, as an example, of more importance to the general interests of humanity than the proudest work of internal improvement that mechanical means have yet constructed. The operations in the Val di Chiana have consisted chiefly in so regulating the flow of the surface-waters into and through it, as to compel them to deposit their sedimentary matter at the will of the engineers, and thereby to raise grounds rendered insalubrious and unfit for agricultural use by stagnating water; the improvements in the Maremma have embraced both this method of elevating the level of the soil, and the prevention of the mixture of salt-water with fresh in the coast marshes and shallow bays, which is regarded as a very active cause of the development of malarious influences.*

---

* The fact that the mixing of salt and fresh water in coast marshes and lagoons is deleterious to the sanitary condition of the vicinity, has been generally admitted, though the precise reason why a mixture of both should be

Improvements in the Tuscan Maremma.

In the improvements of the Tuscan Maremma, formidable difficulties have been encountered. The territory to be reclaimed was extensive; the salubrious places of retreat for laborers and inspectors were remote; the courses of the rivers to be controlled were long and their natural inclination not rapid; some of them, rising in wooded regions, transported comparatively little earthy matter,[*] and above all, the coast,

---

more injurious than either alone, is not altogether clear. It has been suggested that the admission of salt-water to the lagoons and rivers kills many fresh-water plants and animals, while the fresh water is equally fatal to many marine organisms, and that the decomposition of the remains originates poisonous miasmata. Other theories, however, have been proposed. The whole subject is fully and ably discussed by Dr. Salvagnoli Marchetti in the appendix to his valuable *Rapporto sul Bonificamento delle Maremme Toscane*. See also the *Memorie Economico-Statistiche sulle Maremme Toscane*, of the same author. A different view of this subject is taken by RAFFANINI and ORLANDINI in *Analisi, Storico-Fisico-Economica sull' insalubrità nelle Maremme Toscane*, Firenze, 1869. See also the important memoir of D. PANTALEONI, *Del Miasma vegetale e delle Malattie Miasmatiche*, in which the views of Salvagnoli on this point are combated.

[*] This difficulty has been remedied—though with doubtful general advantage—as to one important river of the Maremma, the Pecora, by clearings recently executed along its upper course. "The condition of this marsh and of its affluents are now, November, 1859, much changed, and it is advisable to prosecute its improvement by deposits. In consequence of the extensive felling of the woods upon the plains, hills, and mountains of the territory of Massa and Scarlino, within the last ten years, the Pecora and other affluents of the marsh receive, during the rains, water abundantly charged with slime, so that the deposits within the first division of the marsh are already considerable, and we may now hope to see the whole marsh and pond filled up in a much shorter time than we had a right to expect before 1850. This circumstance totally changes the terms of the question, because the filling of the marsh and pond, which then seemed almost impossible on account of the small amount of sediment deposited by the Pecora, has now become practicable."—SALVAGNOLI, *Rapporto sul Bonificamento delle Maremme Toscane*, pp. li., lii.

Between 1830 and 1859 more than 36,000,000 cubic yards of sediment were deposited in the marsh and shoal-water lake of Castiglione alone.—SALVAGNOLI, *Raccolta di Documenti*, pp. 74, 75.

which is a recent deposit of the waters, is little elevated above the sea, and admits into its lagoons and the mouths of its rivers floods of salt-water with every western wind, every rising tide.*

The western coast of Tuscany is not supposed to have been an unhealthy region before the conquest of Etruria by the Romans, but it certainly became so within a few centuries after that event. This was a natural consequence of the neglect or wanton destruction of the public improvements, and especially the hydraulic works in which the Etruscans were so skilful, and of the felling of the upland forests, to satisfy the demand for wood at Rome for domestic, industrial, and military purposes. After the downfall of the Roman empire, the incursions of the barbarians, and then feudalism, foreign domination, intestine wars, and temporal and spiritual tyrannies, aggravated still more cruelly the moral and physical evils which Tuscany and the other Italian States were doomed to suffer, and from which they have enjoyed but brief respites during the whole period of modern history. The Maremma was already proverbially unhealthy in the time of Dante, who refers to the fact in several familiar passages, and the petty tyrants upon its borders often sent criminals to places of confinement in its territory, as a slow but certain mode of execution. Ignorance of the causes of the insalubrity, and often the interference of private rights, † prevented the adoption of measures to remove it, and the growing political and commercial importance of the large towns in more healthful localities absorbed the attention of Government, and deprived the Maremma of its just share in the systems of physical improvement which were successfully adopted in interior and Northern Italy.

---

* The tide rises ten inches on the coast of Tuscany. See Memoir by FANTONI, in the appendix to SALVAGNOLI, *Rapporto*, p. 189.

On the tides of the Mediterranean, see BÖTTGER, *Das Mittelmeer*, p. 190.

† In Catholic countries, the discipline of the church requires a *meagre* diet at certain seasons, and as fish is not flesh, there is a great demand for that article of food at those periods. For the convenience of monasteries and their patrons, and as a source of pecuniary emolument to ecclesiastical establishments and sometimes to lay proprietors, great numbers of artificial fish-ponds were created during the Middle Ages. They were generally shallow pools formed by damming up the outlet of marshes, and they were among the most fruitful sources of endemic disease, and of the peculiar malignity of the epidemics which so often ravaged Europe in those centuries. These ponds, in religious hands, were too sacred to be infringed upon for sanitary purposes,

Before any serious attempts were made to drain or fill up the marshes of the Maremma, various other sanitary experiments were tried. It was generally believed that the insalubrity of the province was the consequence, not the cause, of its depopulation, and that, if it were once densely inhabited, the ordinary operations of agriculture, and especially the maintenance of numerous domestic fires, would restore it to its ancient healthfulness.* In accordance with these views, settlers were invited from various parts of Italy, from Greece, and, after the accession of the Lorraine princes, from that country also, and colonized in the Maremma. To strangers coming from soils and skies so unlike those of the Tuscan marshes, the climate was more fatal than to the inhabitants of the neighboring districts, whose constitutions had become in some degree inured to the local influences, or who at least knew better how to guard against them. The consequence very naturally was that the experiment totally failed to produce the desired effects, and was attended with a great sacrifice of life and a heavy loss to the treasury of the state.

The territory known as the Tuscan Maremma, *ora maritima*,

---

and when belonging to powerful lay lords they were almost as inviolable. The rights of fishery were a standing obstacle to every proposal of hydraulic improvement, and to this day large and fertile districts in Southern Europe remain sickly and almost unimproved and uninhabited, because the draining of the ponds upon them would reduce the income of proprietors who derive large profits by supplying the faithful, in Lent, with fish, and with various species of waterfowl which, though very fat, are, ecclesiastically speaking, meagre.

* Macchiavelli advised the Government of Tuscany "to provide that men should restore the wholesomeness of the soil by cultivation, and purify the air by fires."—SALVAGNOLI, *Memorie*, p. 111.

or Maremme—for the plural form is most generally used—lies upon and near the western coast of Tuscany, and comprises about 1,900 square miles English, of which 500 square miles, or 320,000 acres, are plain and marsh including 45,500 acres of water surface, and about 290,000 acres are forest. One of the mountain peaks, that of Mount Amiata, rises to the height of 6,280 feet. The mountains of the Maremma are healthy, the lower hills much less so, as the malaria is felt at some points at the height of 1,000 feet, and the plains, with the exception of a few localities favorably situated on the seacoast, are in a high degree pestilential. The fixed population is about 80,000, of whom one-sixth live on the plains in the winter and about one-tenth in the summer. Nine or ten thousand laborers come down from the mountains of the Maremma and the neighboring provinces into the plain, during the latter season, to cultivate and gather the crops.

Out of this small number of inhabitants and strangers, 35,619 were ill enough to require medical treatment between the 1st of June, 1840, and the 1st of June, 1841, and more than one-half the cases were of intermittent, malignant, gastric, or catarrhal fever. Very few agricultural laborers escaped fever, though the disease did not always manifest itself until they had returned to the mountains. In the province of Grosseto, which embraces nearly the whole of the Maremma, the annual mortality was 3.92 per cent., the average duration of life but 23.18 years, and 75 per cent. of the deaths were among persons engaged in agriculture.

The filling up of the low grounds and the partial separation of the waters of the sea and the land, which had been in progress since the year 1827, now began to show very decided effects upon the sanitary condition of the population. In the year ending June 1st, 1842, the number of the sick was reduced by more than 2,000, and the cases of fever by more than 4,000. The next year the cases of fever fell to 10,500, and in that ending June 1st, 1844, to 9,200. The political events of 1848, and the preceding and following years, occasioned the suspension of the works of improvement in the Maremma, but they were resumed after the revolution of 1859.

I have spoken with some detail of the improvements in the Tuscan Maremma, because of their great relative importance, and because their history is well known; but like operations have been executed in the territory of Pisa and upon the coast of the duchy of Lucca. In the latter case they were confined principally to prevention of the intermixing of fresh water with that of the sea. In 1741 sluices or lock-gates were constructed for this purpose, and the following year the fevers, which had been destructive to the coast population for a long time previous, disappeared altogether. In 1768 and 1769, the works having fallen to decay, the fevers returned in a very malignant form, but the rebuilding of the gates again restored the healthfulness of the shore. Similar facts recurred in 1784 and 1785, and again from 1804 to 1821. This long and repeated experience has at last impressed upon the people the necessity of vigilant attention to the sluices, which are now kept in constant repair. The health of the coast is uninterrupted, and Viareggio, the capital town of the district, is now much frequented for its sea-baths and its general salubrity, at a season when formerly it was justly shunned as the abode of disease and death.*

Improvements in the Val di Chiana.

For twenty miles or more after the remotest headwaters of the Arno have united to form a considerable stream, this river flows south-eastwards to the vicinity of Arezzo. It here sweeps round to the north-west, and follows that course to near its junction with the Sieve, a few miles above Florence, from which point its general direction is westward to the sea. From the bend at Arezzo, a depression called the Val di Chiana runs south-eastwards until it strikes into the valley of the Paglia, a tributary of the Tiber, and thus connects the basin of the latter river with that of the Arno. In the Middle Ages, and down to the eighteenth century, the Val di Chiana was often overflowed and devastated by the torrents which poured down from the highlands, transporting great quantities of slime with their currents, stagnating upon its surface, and gradually converting it into a marshy and unhealthy district, which was at last very greatly reduced in population and productiveness. It had, in fact, become so desolate that even the swallow had deserted it.*

---

* GIORGINI, *Sur les causes de l'Insalubrité de l'air dans le voisinage des marais, etc., lue à l'Académie des Sciences à Paris*, le 12 Juillet, 1825. Reprinted in SALVAGNOLI, *Rapporto, etc.*, appendice, p. 5, *et seqq.*

The bed of the Arno near Arezzo and that of the Paglia at the southern extremity of the Val di Chiana did not differ much in level. The general inclination of the valley was therefore small; it does not appear to have ever been divided into opposite slopes by a true watershed, and the position of the summit seems to have shifted according to the varying amount and place of deposit of the sediment brought down by the lateral streams which emptied into it. The length of its principal channel of drainage, and even the direction of its flow at any given point, were therefore fluctuating. Hence, much difference of opinion was entertained at different times with regard to the normal course of this stream, and, consequently, to the question whether it was to be regarded as properly an affluent of the Tiber or of the Arno.

---

* This curious fact is thus stated in the preface to Fossombroni (*Memorie sopra la Val di Chiana*, edition of 1835, p. xiii.), from which also I borrow most of the data hereafter given with respect to that valley: "It is perhaps not universally known, that the swallows, which come from the north [south] to spend the summer in our climate, do not frequent marshy districts with a malarious atmosphere. A proof of the restoration of salubrity in the Val di Chiana is furnished by these aërial visitors, which had never before been seen in those low grounds, but which have appeared within a few years at Forano and other points similarly situated."

Is the air of swamps destructive to the swallows, or is their absence in such localities merely due to the want of human habitations, near which this half-domestic bird loves to breed, perhaps because the house-fly and other insects which follow man are found only in the vicinity of his dwellings?

In almost all European countries the swallow is protected, by popular opinion or superstition, from the persecution to which almost all other birds are subject. It is possible that this respect for the swallow is founded upon ancient observation of the fact just stated on the authority of Fossombroni. Ignorance mistakes the effect for the cause, and the absence of this bird may have been supposed to be the occasion, not the consequence, of the unhealthiness of particular localities. This opinion once adopted, the swallow would become a sacred bird, and in process of time fables and legends would be invented to give additional sanction to the prejudices which protected it. The Romans considered the swallow as consecrated to the Penates, or household gods, and according to Peretti (*Le Serate del Villaggio*, p. 168) the Lombard peasantry think it a sin to kill them, because they are *le gallinelle del Signore*, the chickens of the Lord.

The bed of the latter river at the bend has been eroded to the depth of thirty or forty feet, and that, apparently, at no very remote period.* If it were elevated to what was evidently its original height, the current of the Arno would be so much above that of the Paglia as to allow of a regular flow from its channel to the latter stream, through the Val di Chiana, provided the bed of the valley had remained at the level which excavations prove it to have had a few centuries ago, before it was raised by the deposits I have mentioned. These facts, together with the testimony of ancient geographers which scarcely admits of any other explanation, are thought to prove that all the waters of the Upper Arno were originally discharged through the Val di Chiana into the Tiber, and that a part of them still continued to flow, at least occasionally, in that direction down to the days of the Roman empire, and perhaps for some time later. The depression of the bed of the Arno, and the raising of that of the valley by the deposits of the lateral torrents, finally cut off the branch of the river which had flowed to the Tiber, and all its waters were turned into its present channel, though the drainage of the principal part of the Val di Chiana appears to have been in a south-eastwardly direction until within a comparatively recent period.

---

* Able geologists infer from recent investigations, that, although the Arno flowed to the south within the pliocenic period, the direction of its course was changed at an earlier epoch than that supposed in the text.

In the sixteenth century the elevation of the bed of the valley had become so considerable, that in 1551, at a point about ten miles south of the Arno, it was found to be not less than one hundred and thirty feet above that river; then followed a level of ten miles, and then a continuous descent to the Paglia. Along the level portion of the valley was a boatable channel, and lakes, sometimes a mile or even two miles in breadth, had formed at various points farther south. At this period the drainage of the summit level might easily have been determined in either direction, and the opposite descents of the valley made to culminate at the north or at the south end of the level. In the former case, the watershed would have been ten miles south of the Arno; in the latter, twenty miles, and the division of the valley into two opposite slopes would have been not very unequal.

Various schemes were suggested at this time for drawing off the stagnant waters, as well as for the future regular drainage of the valley, and small operations for those purposes were undertaken with partial success; but it was feared that the discharge of the accumulated waters into the Tiber would produce a dangerous inundation, while the diversion of the drainage into the Arno would increase the violence of the floods to which that river was very subject, and no decisive steps were taken. In 1606 an engineer, whose name has not been preserved, proposed, as the only possible method of improvement, the piercing of a tunnel through the hills bounding the valley on the west to convey its waters to the Ombrone, but the expense and other objections prevented the adoption of this scheme.* The fears of the Roman Government for the safety of the basin of the Tiber had induced it to construct embankments across the portion of the valley lying within its territory, and these obstructions, though not specifically intended for that purpose, naturally promoted the deposit of sediment and the elevation of the bed of the valley in their neighborhood. The effect of this measure and of the continued spontaneous action of the torrents was, that the northern slope, which in 1551 had commenced at the distance of ten miles from the Arno, was found in 1605 to begin nearly thirty miles south of that river, and in 1645 it had been removed about six miles farther in the same direction.[*]

---

* MOROZZI, *Dello stato dell' Arno*, ii., pp. 39, 40.

In the seventeenth century the Tuscan and Papal Governments consulted Galileo, Torricelli, Castelli, Cassini, Viviani, and other distinguished philosophers and engineers, on the possibility of reclaiming the valley by a regular artificial drainage. Most of these eminent physicists were of opinion that the measure was impracticable, though not altogether for the same reasons; but they seem to have agreed in thinking that the opening of such channels, in either direction, as would give the current a flow sufficiently rapid to drain the lands properly, would dangerously augment the inundations of the river—whether the Tiber or the Arno—into which the waters should be turned. The general improvement of the valley was now for a long time abandoned, and the waters were allowed to spread and stagnate until carried off by partial drainage, infiltration, and evaporation. Torricelli had contended that the slope of a large part of the valley was too small to allow it to be drained by ordinary methods, and that no practicable depth and width of canal would suffice for that purpose. It could be laid dry, he thought, only by converting its surface into an inclined plane, and he suggested that this might be accomplished by controlling the flow of the numerous torrents which pour into it, so as to force them to deposit their sediment at the pleasure of the engineer, and, consequently, to elevate the level of the area over which it should be spread.[†] This plan did not meet with immediate general acceptance, but it was soon adopted for local purposes at some points in the southern part of the valley, and it gradually grew in public favor and was extended in application until its final triumph a hundred years later.

---

[*] MOROZZI, *Dello stato, etc., dell' Arno*, ii., pp. 39, 40.

[†] Torricelli thus expressed himself on this point: "If we content ourselves with what nature has made practicable to human industry, we shall endeavor to control, as far as possible, the outlets of these streams, which, by raising the bed of the valley with their deposits, will realize the fable of the Tagus and the Pactolus, and truly roll golden sands for him that is wise enough to avail himself of them."—FOSSOMBRONI, *Memorie sopra la Val di China*, p. 219.

In spite of these encouraging successes, however, the fear of danger to the valley of the Arno and the Tiber, and the difficulty of an agreement between Tuscany and Rome—the boundary between which states crossed the Val di Chiana not far from the half-way point between the two rivers—and of reconciling other conflicting interests, prevented the resumption of the projects for the general drainage of the valley until after the middle of the eighteenth century. In the meantime the science of hydraulics had become better understood, and the establishment of the natural law according to which the velocity of a current of water, and of course the proportional quantity discharged by it in a given time, are increased by increasing its mass, had diminished if not dissipated the fear of exposing the banks of the Arno to greater danger from inundations by draining the Val di Chiana into it.

The suggestion of Torricelli was finally adopted as the basis of a comprehensive system of improvement, and it was decided to continue and extend the inversion of the original flow of the waters, and to turn them into the Arno from a point as far to the south as should be found practicable. The conduct of the works was committed to a succession of able engineers who, for a long series of years, were under the general direction of the celebrated philosopher and statesman Fossombroni, and the success has fully justified the expectations of the most sanguine advocates of the scheme. The plan of improvement embraced two branches: the one, the removal of obstructions in the bed of the Arno, and, consequently, the further depression of the channel of that river, in certain places, with the view of increasing the rapidity of its current; the other, the gradual filling up of the ponds and swamps, and raising of the lower grounds of the Val di Chiana, by directing to convenient points the flow of the streams which pour down into it, and there confining their waters by temporary dams until the sediment was deposited where it was needed. The economical result of these operations has been, that in 1835 an area of more than four hundred and fifty square miles of pond, marsh, and damp, sickly low grounds had been converted into fertile, healthy, and well-drained soil, and, consequently, that so much territory has been added to the agricultural domain of Tuscany.

But in our present view of the subject, the geographical revolution which has been accomplished is still more interesting. The climatic influence of the elevation and draining of the soil must have been considerable, though I do not know that an increase or a diminution of the mean temperature or precipitation in the valley has been established by meteorological observation. There is, however, in the improvement of the sanitary condition of the Val di Chiana, which was formerly extremely unhealthy, satisfactory proof of a beneficial climatic change. The fevers, which not only decimated the population of the low grounds but infested the adjacent hills, have ceased their ravages, and are now not more frequent than in other parts of Tuscany. The strictly topographical effect of the operations in question, besides the conversion of marsh into dry surface, has been the inversion of the inclination of the valley for a distance of thirty-five miles, so that this great plain which, within a comparatively short period, sloped and drained its waters to the south, now inclines and sends its drainage to the north. The reversal of the currents of the valley has added to the Arno a new tributary equal to the largest of its former affluents, and a most important circumstance connected with this latter fact is, that the increase of the volume of its waters has accelerated their velocity in a still greater proportion, and, instead of augmenting the danger from its inundations, has almost wholly obviated that source of apprehension.* Between the beginning of the fifteenth century and the year 1761, thirty-one destructive floods of the Arno are recorded; between 1761, when the principal streams of the Val di Chiana were diverted into that river, and 1835, not one.*

---

* Arrian observes that at the junction of the Hydaspes and the Acesines, both of which are described as wide streams, "one very narrow river is form-

---

ed of two confluents, and its current is very swift."—ARRIAN, *Alex. Anab.*, vi., 4.

A like example is observed in the Anapus near Syracuse, which, below the junction of its two branches, is narrower, though swifter than either of them, and such cases are by no means unfrequent. The immediate effect of the confluence of two rivers upon the current below depends upon local circumstances, and especially upon the angle of incidence. If the two nearly coincide in direction, so as to include a small angle, the joint current will have a greater velocity than the slower confluent, perhaps even than either of them. If the two rivers run in transverse, still more if they flow in more or less opposite, directions, the velocity of the principal branch will be retarded both above and below the junction, and at high water it may even set back the current of the affluent.

On the other hand, the diversion of a considerable branch from a river retards its velocity below the point of separation, and here a deposit of earth in its channel immediately begins, which has a tendency to turn the whole stream into the new bed. "Theory and the authority of all hydrographical writers combine to show that the channels of rivers undergo an elevation of bed below a canal of diversion."—Letter of FOSSOMBRONI, in SALVAGNOLI, *Raccolta di Documenti*, p. 32. See the early authorities and discussions on the principle stated in the text, in FRISI, *Del modo di regolare i Fiumi e i Torrenti*, libro iii., capit. i., and MONGOTTI, *Idraulica*, ii., pp. 88 et seqq., and see p. 498, *note*, *ante*.

In my account of these improvements I have chiefly followed Fossombroni, under whose direction they were principally executed. Many of Fossombroni's statements and opinions have been controverted, and in comparatively unimportant particulars they have been shown to be erroneous.—See LOMBARDINI, *Guida allo studio dell' Idrologia*, cap. xviii., and same author, *Esame degli Studi sul Tevere*, § 33.

* FOSSOMBRONI, *Memorie Idraulico-storiche*, *Introduzione*, p. xvi. Between the years 1700 and 1799 the chroniclers record seventeen floods of the Arno, and twenty between 1800 and 1870, but none of these were of a properly destructive character except those of 1844, 1864, and 1870, and the ravages of this latter were chiefly confined to Pisa, and were occasioned by the bursting of a dike or wall. They are all three generally ascribed to extraordinary, if not unprecedented, rains and snows, but many inquirers attribute them to the felling of the woods in the valleys of the upper tributaries of the Arno since 1835. See a paper by GRIFFINI, in the *Italia Nuova*, 18 Marzo, 1871.

Results of Operations.

It is now a hundred years since the commencement of the improvements in the Val di Chiana, and those of the Maremma have been in more or less continued operation for above a generation. They have, as we have seen, produced important geographical changes in the surface of the earth and in the flow of considerable rivers, and their effects have been not less conspicuous in preventing other changes, of a more or less deleterious character, which would infallibly have taken place if they had not been arrested by the improvements in question.

The sediment washed into the marshes of the Maremma is not less than 12,000,000 cubic yards per annum. The escape of this quantity into the sea, which is now almost wholly prevented, would be sufficient to advance the coast-line fourteen yards per year, for a distance of forty miles, computing the mean depth of the sea near the shore at twelve yards. It is true that in this case, as well as in that of other rivers, the sedimentary matter would not be distributed equally along the shore, and much of it would be carried out into deep water, or perhaps transported by the currents to distant coasts. The immediate effects of the deposit in the sea, therefore, would not be so palpable as they appear in this numerical form, but they would be equally certain, and would infallibly manifest themselves, first, perhaps, at some remote point, and afterwards more energetically at or near the outlets of the rivers which produced them. The elevation of the bottom of the sea would diminish the inclination of the beds of the rivers discharging themselves into it on that coast, and of course their tendency to overflow their banks and extend still further the domain of the marshes which border them would be increased in proportion.

It has been already stated that, in order to prevent the overflow of the valley of the Tiber by freely draining the Val di Chiana into it, the Papal authorities, long before the commencement of the Tuscan works, constructed strong barriers near the southern end of the valley, which detained the waters of the wet season until they could be gradually drawn off into the Paglia. They consequently deposited most of their sediment in the Val di Chiana and carried down comparatively little earth to the Tiber. The lateral streams contributing the largest quantities of sedimentary matter to the Val di Chiana originally flowed into that valley near its northern end; and the change of their channels and outlets in a southern direction, so as to raise that part of the valley by their deposits and thereby reverse its drainage, was one of the principal steps in the process of improvement.

We have seen that the north end of the Val di Chiana near the Arno had been raised by spontaneous deposit of sediment to such a height as to interpose a sufficient obstacle to all flow in that direction. If, then, the Roman dam had not been erected, or the works of the Tuscan Government undertaken, the whole of the earth, which has been arrested by those works and employed to raise the bed and reverse the declivity of the valley, would have been carried down to the Tiber and thence into the sea. The deposit thus created would, of course, have contributed to increase the advance of the shore at the mouth of that river, which has long been going on at the rate of three mètres and nine-tenths (twelve feet and nine inches) per annum.* It is evident that a quantity of earth, sufficient to effect the immense changes I have described in a wide valley more than thirty miles long, if deposited at the outlet of the Tiber, would have very considerably modified the outline of the coast, and have exerted no unimportant influence on the flow of that river, by raising its point of discharge and lengthening its channel.

The Coast of the Netherlands.

It has been shown in a former section that the dikes of the

---

* See the careful estimates of ROZET, *Moyens de forcer les Torrents*, etc., pp. 42, 44.

Netherlands and the adjacent states have protected a considerable extent of coast from the encroachments of the sea, and have won a large tract of cultivable land from the dominion of the ocean waters. The immense results obtained from the operations of the Tuscan engineers in the Val di Chiana, and the Maremma have suggested the question, whether a different method of accomplishing these objects might not have been adopted with advantage. It has been argued, as in the case of the Po, that a system of transverse inland dikes and canals, upon the principle of those which have been so successfully employed in the Val di Chiana and in Egypt, might have elevated the low grounds above the ocean tides, by spreading over them the sediment brought down by the Rhine, the Maes, and the Scheld. If this process had been introduced in the Middle Ages, and constantly pursued to our times, the superficial and coast geography, as well as the hydrography of the countries in question, would undoubtedly have presented an aspect very different from their present condition; and by combining the process with a system of maritime dikes, which would have been necessary, both to resist the advance of the sea and to retain the slime deposited by river overflows, it is, indeed, possible that the territory of those states would have been as extensive as it now is, and, at the same time, somewhat elevated above its natural level.

The argument in favor of that method rests on the assumption that all the sea-washed earth, which the tides have let fall upon the shallow coast of the Netherlands, has been brought down by the rivers which empty upon those shores, and could have been secured by allowing those rivers to spread over the flats and deposit their sediment in still-water pools formed by cross-dikes like those of Egypt.

But we are ignorant of the proportions in which the marine deposits that form the soil of the polders have been derived from materials brought down by these rivers, or from other more remote sources. Much of the river slime has, no doubt, been transported by marine currents quite beyond the reach of returning streams, and it is uncertain how far this loss has been balanced by earth washed by the sea from distant shores and let fall on the coasts of the Netherlands and other neighboring countries.

We know little or nothing of the quantity of solid matter brought down by the rivers of Western Europe in early ages, but, as the banks of those rivers are now generally better secured against wash and abrasion than in former centuries, the sediment transported by them must be less than at periods nearer the removal of the primitive forests of their valleys, though certainly greater than it was before those forests were felled. Kläden informs us that the sedimentary matter transported to the sea by the Rhine would amount to a cubic geographical mile in five thousand years.*

The proportion of this suspended matter which, with our present means, could be arrested and precipitated upon the ground, is almost infinitesimal, for only the surface-water, which carries much less sediment than that at the bottom of the channel, would flow over the banks, and as the movement of this water, if not checked altogether, would be greatly retarded by the proposed cross-dikes, the quantity of solid matter which would be conveyed to a given portion of land during a single inundation would be extremely small. Inundations of the Rhine occur but once or twice a year, and high water continues but a few days, or even hours; the flood-tide of the sea happens seven hundred times in a year, and at the turn of the tide the water is brought to almost absolute rest. Hence, small as is the proportion of suspended matter in the tide-water, the deposit probably amounts to far more in a year than would be let fall upon the same area by the Rhine.

This argument, except as to the comparison between river and tide water, applies to the Mississippi, the Po, and most other great rivers. Hence, until that distant day when man shall devise means of extracting from rivers at flood, the whole volume of their suspended material and of depositing it at the same time on their banks, the system of cross-dikes and *colmatage* must be limited to torrential streams transporting large proportions of sediment, and to the rivers of hot countries, like the Nile, where the saturation of the soil with water, and the securing of a supply for irrigation afterwards, are the main objects, while raising the level of the banks is a secondary consideration.

---

* *Erdkunde*, vol. i., p. 384. The Mississippi—a river "undercharged with sediment"—with a mean discharge of about ten times that of the Rhine, deposits a cubic geographical mile in thirty-three years.

CHAPTER V.

THE SANDS.

Origin of Sand—Sand now Carried to the Sea—Beach Sands of Northern Africa—Sands of Egypt—Sand Dunes and Sand Plains—Coast Dunes—Sand Banks—Character of Dune Sand—Interior Structure of Dunes—Geological Importance of Dunes—Dunes on American Coasts—Dunes of Western Europe—Age, Character, and Permanence of Dunes—Dunes as a Barrier against the Sea—Encroachments of the Sea—Liimfjord—Coasts of Schleswig-Holstein, Netherlands, and France—Movement of Dunes—Control of Dunes by Man—Inland Dunes—Inland Sand Plains.

Origin of Sand.

SAND, which is found in beds or strata at the bottom of the sea or in the channels of rivers, as well as in extensive deposits upon or beneath the surface of the dry land, appears to consist essentially of the detritus of rocks. It is not always by any means clear through what agency the solid rock has been reduced to a granular condition; for there are beds of quartzose sand, where the sharp, angular shape of the particles renders it highly improbable that they have been formed by gradual abrasion and attrition, and where the supposition of a crushing mechanical force seems equally inadmissible. In common sand, the quartz grains are the most numerous; but this is not a proof that the rocks from which these particles were derived were wholly, or even chiefly, quartzose in character; for, in many composite rocks, as, for example, in the granitic group, the mica, felspar, and hornblende are more easily decomposed by chemical action, or disintegrated, comminuted, and reduced to an impalpable state by mechanical force, than the quartz. In the destruction of such rocks, therefore, the quartz would survive the other ingredients, and remain un-vise means of extracting from rivers at flood, the whole volume of their suspended material and of depositing it at the same time on their banks, the system of cross-dikes and *colmatage* must be limited to torrential streams transporting large proportions of sediment, and to the rivers of hot countries, like the Nile, where the saturation of the soil with water, and the securing of a supply for irrigation afterwards, are the main objects, while raising the level of the banks is a secondary consideration.

sand now transported to the sea seems to be comparatively inconsiderable, because—not to speak of the absence of diluvial action—the number of torrents emptying directly into the sea is much less than it was at earlier periods. The formation of alluvial plains in maritime bays, by the sedimentary matter brought down from the mountains, has lengthened the flow of such streams and converted them very generally into rivers, or rather affluents of rivers of later geographical origin than themselves. The filling up of the estuaries has so reduced the slope of all large and many small rivers, and, consequently, so checked the current of what the Germans call their *Unterlauf*, or lower course, that they are much less able to transport heavy material than at earlier epochs. The slime deposited by rivers at their junction with the sea, is usually found to be composed of material too finely ground and too light to be denominated sand, and it can be abundantly shown that the sand-banks at the outlet of most large streams are of tidal, not of fluviatile, accumulation, or, in lakes and tideless seas, a result of the concurrent action of waves and of wind.

Large deposits of sand, therefore, must in general be considered as of ancient, not of recent formation, and many eminent geologists ascribe them to diluvial action. Staring has discussed this question very fully, with special reference to the sands of the North Sea, the Zuiderzee, and the bays and channels of the Dutch coast.[*] His general conclusion is, that the rivers of the

---

[*] *De Bodem van Nederland*, i., pp. 243, 246–377 *et seqq.* See also the arguments of Brémontier as to the origin of the dune-sands of Gascony, *Annales des Ponts et Chaussées*, 1833, 1er sémestre, pp. 158, 161. Brémontier estimates the sand annually thrown up on that coast at five cubic toises and two feet to the running toise (ubi supra, p. 162), or rather more than two hundred and twenty cubic feet to the running foot. Laval, upon observations continued through seven years, found the quantity to be twenty-five mètres per running mètre, which is equal to two hundred and sixty-eight cubic feet to the running foot.—*Annales des Ponts et Chaussées*, 1842, 2me sémestre, p. 229. These computations make the proportion of sand deposited on the coast of Gascony three or four times as great as that observed by Andresen on the shores of Jutland. Laval estimates the total quantity of sand annually thrown up on the coast of Gascony at 6,000,000 cubic mètres, or more than 7,800,000 cubic yards.

Netherlands "move sand only by a very slow displacement of sand-banks, and do not carry it with them as a suspended or floating material." The sands of the German Ocean he holds to be a product of the "great North German drift," deposited where they now lie before the commencement of the present geological period, and he maintains similar opinions with regard to the sands thrown up by the Mediterranean at the mouths of the Nile and on the Barbary coast.*

Sand now carried to the Sea.

There are, however, cases where mountain streams still bear to the sea perhaps relatively small, but certainly absolutely large, amounts of disintegrated rock.† The quantity of sand

---

* *De Bodem van Nederland*, i., p. 339.

† The conditions favorable to the production of sand from disintegrated rock, by causes now in action, are perhaps nowhere more perfectly realized than in the Sinaitic Peninsula. The mountains are steep and lofty, unprotected by vegetation or even by a coating of earth, and the rocks which compose them are in a shattered and fragmentary condition. They are furrowed by deep and precipitous ravines, with beds sufficiently inclined for the rapid flow of water, and generally without basins in which the larger blocks of stone rolled by the torrents can be dropped and left in repose; there are severe frosts and much snow on the higher summits and ridges, and the winter rains are abundant and heavy. The mountains are principally of igneous formation, but many of the less elevated peaks are capped with sandstone, and on the eastern slope of the peninsula you may sometimes see, at a single glance, several lofty pyramids of granite, separated by considerable intervals, and all surmounted by horizontally stratified deposits of sandstone often only a few yards square, which correspond to each other in height, are evidently contemporaneous in origin, and were once connected in continuous beds. The degradation of the rock on which this formation rests is constantly bringing down masses of it, and mingling them with the basaltic, porphyritic, granitic, and calcareous fragments which the torrents carry down to the valleys, and, through them, in a state of greater or less disintegration, to the sea. The quantity of sand annually washed into the Red Sea by the larger torrents of the Lesser Peninsula, is probably at least equal to that contributed to the ocean by any streams draining basins of no greater extent. Absolutely considered, then, the mass may be said to be large, but it is apparently very small as compared with the sand thrown up by the German Ocean and the Atlantic on the coasts of Denmark and of France. There are, indeed, in Arabia Petræa, many torrents

and gravel carried into the Mediterranean by the torrents of the Maritime Alps, the Ligurian Apennines, the islands of Corsica, Sardinia, and Sicily, and the mountains of Calabria, is apparently great. In mere mass, it is possible, if not probable, that as much rocky material, more or less comminuted, is contributed to the basin of the Mediterranean by Europe, even excluding the shores of the Adriatic and the Euxine, as is washed up from it upon the coasts of Northern Africa and Syria. A great part of this material is thrown out again by the waves on the European shores of that sea. The harbors of Luni, Albenga, San Remo, and Savona west of Genoa, and of Porto Fino on the other side, are filling up, and the coast near Carrara and Massa is said to have advanced upon the sea to a distance of 475 feet in thirty-three years.[*] Besides this, we have no evidence of the existence of deep-water currents in the Mediterranean, extensive enough and strong enough to transport quartzose sand across

---

with very short courses, for the sea-waves in many parts of the peninsular coast wash the base of the mountains. In these cases, the débris of the rocks do not reach the sea in a sufficiently comminuted condition to be entitled to the appellation of sand, or even in the form of well-rounded pebbles. The fragments retain their annular shape, and, at some points on the coast, they become cemented together by lime or other binding substances held in solution or mechanical suspension in the sea-water, and are so rapidly converted into a singularly heterogeneous conglomerate, that one deposit seems to be consolidated into a breccia before the next winter's torrents cover it with another.

In the northern part of the peninsula there are extensive deposits of sand intermingled with agate pebbles and petrified wood, but these are evidently neither derived from the Sinaitic group, nor products of local causes known to be now in action.

I may here notice the often repeated but mistaken assertion, that the petrified wood of the Western Arabian desert consists wholly of the stems of palms, or at least of endogenous vegetables. This is an error. I have myself picked up in that desert, within the space of a very few square yards, fragments apperently of fossil palms, and of at least two petrified trees distinctly marked as of exogenous growth both by annular structure and by knots. In ligneous character, one of these almost precisely resembles the grain of the extant beech, and this specimen was worm-eaten before it was converted into silex.

[*] BÖTTGER, *Das Mittelmeer*, p. 128.

the sea. It may be added that much of the rock from which the torrent sands of Southern Europe are derived contains little quartz, and hence the general character of these sands is such that they must be decomposed or ground down to an impalpable slime, long before they could be swept over to the African shore.

Sands of Northern Africa.

The torrents of Europe, then, do not at present furnish the material which composes the beach sands of Northern Africa, and it is equally certain that those sands are not brought down by the rivers of the latter continent. They belong to a remote geological period, and have been accumulated by causes which we cannot at present assign. The wind does not stir water to great depths with sufficient force to disturb the bottom,* and

---

* The testimony of divers and of other observers on this point is conflicting, as might be expected from the infinite variety of conditions by which the movement of water is affected. It is generally believed that the action of the wind upon the water is not perceptible at greater depths than from fifteen feet in ordinary to eighty or ninety in extreme cases; but these estimates are probably very considerably below the truth. Andresen quotes Brémontier as stating that the movement of the waves sometimes extends to the depth of five hundred feet, and he adds that others think it may reach to six or even seven hundred feet below the surface.—ANDRESEN, *Om Klitformationen*, p. 20.

Many physicists now suppose that the undulations of great bodies of water reach even deeper. But a movement of undulation is not necessarily a movement of translation, and besides, there is very frequently an undertow, which tends to carry suspended bodies out to sea as powerfully as the superficial waves to throw them on shore. Sand-banks sometimes recede from the coast, instead of rolling towards it. Reclus informs us that the Mauvaise, a sand-bank near the Point de Grave, on the Atlantic coast of France, has moved five miles to the west in less than a century.—*Revue des Deux Mondes* for December, 1862, p. 905.

The action of currents may, in some cases, have been confounded with that of the waves. Sea-currents, strong enough, possibly, to transport sand for some distance, flow far below the surface in parts of the open ocean, and in narrow straits they have great force and velocity. The divers employed at Constantinople in 1853 found in the Bosphorus, at the depth of twenty-five fathoms and at a point much exposed to the wash from Galata and Pera, a the sand thrown upon the coast in question must be derived from a narrow belt of sea. It must hence, in time, become exhausted, and the formation of new sand-banks and dunes upon the southern shores of the Mediterranean will cease at last for want of material.*

But even in the cases where the accumulations of sand in extensive deserts appear to be of marine formation, or rather aggregation, and to have been brought to their present position by upheaval, they are not wholly composed of material collected or distributed by the currents of the sea; for, in all such regions, they continue to receive some small contributions from the disintegration of the rocks which underlie, or crop out through, the superficial deposits.† In some instances, too, as in

---

number of bronze guns supposed to have belonged to a ship-of-war blown up about a hundred and fifty years before. These guns were not covered by sand or slime, though a crust of earthy matter, an inch in thickness, adhered to their upper surfaces, and the bottom of the strait appeared to be wholly free from sediment. The current was so powerful at this depth that the divers were hardly able to stand, and a keg of nails, purposely dropped into the water, in order that its movements might serve as a guide in the search for a bag of coin accidentally lost overboard from a ship in the harbor, was rolled by the stream several hundred yards before it stopped.

* Few seas have thrown up so much sand as the shallow German Ocean; but there is some reason to think that the amount of this material now cast upon its northern shores is less than at some former periods, though no extensive series of observations on this subject has been recorded. On the Spit of Agger, at the present outlet of the Liimfjord, Andresen found the quantity during ten years, on a beach about five hundred and seventy feet broad, equal to an annual deposit of an inch and a half over the whole surface.—*Om Klitformationen*, p. 56.

This gives seventy-one and a quarter cubic feet to the running foot—a quantity certainly much smaller than that cast up by the same sea on the shores of the Dano-German duchies and of Holland, and, as we have seen, scarcely one-fourth of that deposited by the Atlantic on the coast of Gascony.

† See, on this subject, an article in *Aus der Natur*, vol. xxx., p. 590.

The Florentine Frescobaldi, who visited the Sinaitic peninsula five hundred years ago, observed the powerful action of the solar heat in the disintegration of the desert rocks. "This place," says he, "was a ridge of rocks burnt to powder by the sun, and this powder is blown away from the rock by the wind and is the sand of the desert; and there be many hills which are pure bare

Northern Africa, additions are constantly made to the mass by the prevalence of sea-winds, which transport, or, to speak more precisely, roll the finer beach-sand to considerable distances into the interior. But this is a very slow process, and the exaggerations of travellers have diffused a vast deal of popular error on the subject.

Sands of Egypt.

In the narrow valley of the Nile—which, above its bifurcation near Cairo, is, throughout Egypt and Nubia, generally bounded by precipitous cliffs—wherever a ravine or other considerable depression occurs in the wall of rock, one sees what seems a stream of desert sand pouring down, and common observers have hence concluded that the whole valley is in danger of being buried under a stratum of infertile soil. The ancient Egyptians apprehended this, and erected walls, often of unburnt brick, across the outlet of gorges and lateral valleys, to check the flow of the sand-streams. In later ages, these walls have mostly fallen into decay, and no preventive measures against such encroachments are now resorted to. But the extent of the mischief to the soil of Egypt, and the future danger from this source, have been much overrated. The sand on the borders of the Nile is neither elevated so high by the wind, nor transported by that agency in so great masses, as is popularly supposed; and of that which is actually lifted or rolled and finally deposited by air-currents, a considerable

---

rock, and when the sun parcheth them, the wind carries off the dust, and other sand is there none in that land."—*Viaggio*, pp. 69, 70.

In Arabia Petræa, when a wind, powerful enough to scour down below the ordinary surface of the desert and lay bare a fresh bed of stones, is followed by a sudden burst of sunshine, the dark agate pebbles are often cracked and broken by the heat; and this is the true explanation of the occurrence of the fragments in situations where the action of fire is not probable. If the fragments are small enough to be rolled by the winds, they are in time ground down to sand and contribute to the stock of that material which covers the face of the desert, though the sand thus formed is but an infinitesimal proportion of the whole.

proportion is either calcareous, and, therefore, readily decomposable, or in the state of a very fine dust, and so, in neither case, injurious to the soil. There are, indeed, both in Africa and in Arabia, considerable tracts of fine, silicious sand, which may be carried far by high winds, but these are exceptional cases, and in general the progress of the desert sand is by a rolling motion along the surface.* So little is it lifted, and so inconsiderable is the quantity yet remaining on the borders of Egypt, that a wall four or five feet high suffices for centuries to check its encroachments. This is obvious to the eye of every observer who prefers the true to the marvellous; but the old-world fable of the overwhelming of caravans by the fearful simoom—which even the Arabs no longer repeat, if indeed they are the authors of it—is so thoroughly rooted in the imagination of Christendom that most desert travellers, of the tourist class, think they shall disappoint the readers of their journals if they do not recount the particulars of their escape from being buried alive by a sand-storm, and the popular demand for a "sensation" must be gratified accordingly.[*]

---

* Sand heaps, three and even six hundred feet high, are indeed formed by the wind, but this is effected by driving the particles up an inclined plane, not by lifting them. Brémontier, speaking of the sand-hills on the western coast of France, says: "The particles of sand composing them are not large enough to resist wind of a certain force, nor small enough to be taken up by it, like dust; they only roll along the surface from which they are detached, and, though moving with great velocity, they rarely rise to a greater height than three or four inches."—*Mémoire sur les Dunes*, *Annales des Ponts et Chaussées*, 1833, 1er sémestre, p. 148.

Andresen says that a wind, having a velocity of forty feet per second, is strong enough to raise particles of sand as high as the face and eyes of a man, but that, in general, it rolls along the ground, and is scarcely ever thrown more than to the height of a couple of yards from the surface. Even in these cases, it is carried forward by a hopping, not a continuous, motion; for a very narrow sheet or channel of water stops the drift entirely, all the sand dropping into it until it is filled up.

Blake observes, *Pacific Railroad Report*, vol. v., p. 242, that the sand of the Colorado desert does not rise high in the air, but bounds along on the surface or only a few inches above it.

The character of the motion of sand drifts is well illustrated by an interesting fact not much noticed hitherto by travellers in the East. In situations where the sand is driven through depressions in rock-beds, or over deposits of silicious pebbles, the surface of the stone is worn and smoothed much more effectually than it could be by running water, and I have picked up, in such localities, rounded, irregularly broken fragments of agate, which had received from the attrition of the sand as fine a polish as could be given them by the wheel of the lapidary.

Very interesting observations, by Blake, on the polishing of hard stones by drifting sand will be found in the *Pacific Railroad Report*, vol. v., pp. 92, 230, 231.

The grinding and polishing power of sand has lately received a new and most ingenious application in America. Jets of sand, and even of small particles of softer substances, thrown with a certain force, are found capable of cutting the hardest minerals and metals. A block of corundum, some inches thick, has been bored through in a few minutes by this process, and it promises to be highly useful in glass-cutting and other similar operations.

Another circumstance is necessary to be considered in estimating the danger to which the arable lands of Egypt are exposed. The prevailing wind in the valley of the Nile and its borders is from the north, and it may be said without exaggeration that the north wind blows for three-quarters of the year.[†] The effect of winds blowing up the valley is to drive the sands of the desert plateau which border it, in a direction parallel with the axis of the valley, not transversely to it; and if it ran in a straight line, the north wind would carry no desert sand into it. There are, however, both curves and angles in its course, and hence, wherever its direction deviates from that of the wind, it might receive sand-drifts from the desert plain through which it runs. But, in the course of ages, the winds have, in a great measure, bared the projecting points of their ancient deposits, and no great accumulations remain in situations from which either a north or a south wind would carry them into the valley.*

---

[*] Wilkinson says that, in much experience in the most sandy parts of the Libyan desert, and much inquiry of the best native sources, he never saw or heard of any instance of danger to man or beast from the mere accumulation of sand transported by the wind. Chesney's observations in Arabia, and the testimony of the Bedouins he consulted, are to the same purpose. The dangers of the simoom are of a different character, though they are certainly aggravated by the blinding effects of the light particles of dust and sand borne along by it, and by that of the inhalation of them upon the respiration.

[†] In the narrow valley of the Nile, bounded as it is, above the Delta, by high cliffs, all air-currents from the northern quarter become north winds, though of course varying in partial direction, in conformity with the sinuosities of the valley. Upon the desert plateau they incline westwards, and have already borne into the valley the sands of the eastern banks, and driven those of the western quite out of the Egyptian portion of the Nile basin.

The sand let fall in Egypt by the north wind is derived, not from the desert, but from a very different source—the sea. Considerable quantities of sand are thrown up by the Mediterranean, at and between the mouths of the Nile, and indeed along almost the whole southern coast of that sea, and drifted into the interior to distances varying according to the force of the wind and the abundance and quality of the material. The sand so transported contributes to the gradual elevation of the Delta, and of the banks and bed of the river itself. But just in proportion as the bed of the stream is elevated, the height of the water in the annual inundations is increased also, and as the inclination of the channel is diminished, the rapidity of the current is checked, and the deposition of the slime it holds in suspension consequently promoted. Thus the winds and the water, moving in contrary directions, join in producing a common effect.

---

* These considerations apply, with equal force, to the supposed danger of the obstruction of the Suez Canal by the drifting of the desert sands. The winds across the isthmus are almost uniformly from the north, and they swept it comparatively clean of flying sands long ages since. The traces of the ancient canal between the Red Sea and the Nile are easily followed for a considerable distance from Suez. Had the drifts upon the isthmus been as formidable as some have feared and others have hoped, those traces would have been obliterated, and Lake Timsah and the Bitter Lakes filled up, many centuries ago. The few particles driven by the rare east and west winds towards the line of the canal, will easily be arrested by plantations or other simple methods, or removed by dredging. The real dangers and difficulties of this magnificent enterprise—and they have been great—consisted in the nature of the soil to be removed in order to form the line, and especially in the constantly increasing accumulation of sea-sand at the southern terminus by the tides of the Red Sea, and of sand and Nile slime at the northern, by the action of the winds and currents. Both seas are shallow for miles from the shore, and the excavation and maintenance of deep channels, and of capacious harbors with easy and secure entrances, in such localities, is doubtless one of the hardest problems offered to modern engineers for practical solution. See *post*, *Geological Importance of Dunes*, *note*.

The sand, blown over the Delta and the cultivated land higher up the stream during the inundation, is covered or mixed with the fertile earth brought down by the river, and no serious injury is sustained from it. That spread over the same ground after the water has subsided, and during the short period when the soil is not stirred by cultivation or covered by the flood, forms a thin pellicle over the surface as far as it extends, and serves to divide and distinguish the successive layers of slime deposited by the annual inundations. The particles taken up by the wind on the sea-beach are borne onward, by a hopping motion, or rolled along the surface, until they are arrested by the temporary cessation of the wind, by vegetation, or by some other obstruction, and they may, in process of time, accumulate in large masses, under the lee of rocky projections, buildings, or other barriers which break the force of the wind.

In these facts we find an important element in the explanation of the sand drifts, which have half buried the Sphinx and so many other ancient monuments in that part of Egypt. These drifts, as I have said, are not wholly from the desert, but in large proportion from the sea; and, as might be supposed from the distance they have travelled, they have been long in gathering. While Egypt was a great and flourishing kingdom, measures were taken to protect its territory against the encroachment of sand, whether from the desert or from the Mediterranean; but the foreign conquerors, who destroyed so many of its religious monuments, did not spare its public works, and the process of physical degradation undoubtedly began as early as the Persian invasion. The urgent necessity, which has compelled all the successive tyrannies of Egypt to keep up some of the canals and other arrangements for irrigation, was not felt with respect to the advancement of the sands; for their progress was so slow as hardly to be perceptible in the course of a single reign, and long experience has shown that, from the natural effect of the inundations, the cultivable soil of the valley is, on the whole, trenching upon the domain of the desert, not retreating before it.

The oases of the Libyan, as well as of many Asiatic deserts, have no such safeguards. The sands are fast encroaching upon them, and threaten soon to engulf them, unless man shall resort to artesian wells and plantations, or to some other efficient means of checking the advance of this formidable enemy, in time to save these islands of the waste from final destruction.

Accumulations of sand are, in certain cases, beneficial as a protection against the ravages of the sea; but, in general, the vicinity, and especially the shifting of bodies of this material, are destructive to human industry, and hence, in civilized countries, measures are taken to prevent its spread. This, however, can be done only where the population is large and enlightened, and the value of the soil, or of the artificial erections and improvements upon it, is considerable. Hence in the deserts of Africa and of Asia, and the inhabited lands which border on them, no pains are usually taken to check the drifts, and when once the fields, the houses, the springs, or the canals of irrigation are covered or choked, the district is abandoned without a struggle, and surrendered to perpetual desolation.[*]

---

[*] In parts of the Algerian desert, some efforts are made to retard the advance of sand dunes which threaten to overwhelm villages. "At Debila," says Laurent, "the lower parts of the lofty dunes are planted with palms, . . . but they are constantly menaced with burial by the sands. The only remedy employed by the natives consists in little dry walls of crystallized gypsum, built on the crests of the dunes, together with hedges of dead palm-leaves. These defensive measures are aided by incessant labor; for every day the people take up in baskets the sand blown over to them the night before and carry it back to the other side of the dune."—*Mémoires sur le Sahara*, p. 14.

Sand Dunes and Sand Plains.

Two forms of sand deposit are specially important in European and American geography. The one is that of dune or shifting hillock upon the coast, the other that of barren plain in the interior. The coast-dunes are composed of sand washed up from the depths of the sea by the waves, and heaped in more or less rounded knolls and undulating ridges by the winds. The sand with which many plains are covered appears sometimes to have been deposited upon them while they were yet submerged beneath the sea, sometimes to have been drifted from the seacoast, and scattered over them by wind-currents, sometimes to have been washed upon them by running water. In these latter cases, the deposit, though in itself considerable, is comparatively narrow in extent and irregular in distribution, while, in the former, it is often evenly spread over a very wide surface. In all great bodies of either sort, the silicious grains are the principal constituent, though, when not resulting from the disintegration of silicious rock and still remaining in place, they are generally accompanied with a greater or less admixture of other mineral particles, and of animal and vegetable remains,[*] and they are, also, usually somewhat changed in consistence by the ever-varying conditions of temperature and moisture to which they have been exposed since their deposit. Unless the proportion of these latter ingredients is so large as to create a considerable adhesiveness in the mass—in which case it can no longer properly be called sand—it is infertile, and, if not charged with water, partially agglutinated by iron, lime, or other cement, or confined by alluvion resting upon it, it is much inclined to drift, whenever, by any chance, the vegetable network which, in most cases, thinly clothes and at the same time confines it, is broken.

---

[*] Organic constituents, such as comminuted shells, and silicious and calcareous exuviæ of infusorial animals and plants, are sometimes found mingled in considerable quantities with mineral sands. These are usually the remains of aquatic vegetables or animals, but not uniformly so, for the microscopic organisms, whose flinty cases enter so largely into the sand-beds of the Mark of Brandenburg, are still living and prolific in the dry earth. See WITTWER, *Physikalische Geographie*, p. 142.

The desert on both sides of the Nile is inhabited by a land-snail—of which I have counted eighty, in estimation, on a single shrub barely a foot high—and thousands of its shells are swept along and finally buried in the drifts by every wind. Every handful of the sand contains fragments of them. FORCHHAMMER, in LEONHARD und BRONN'S *Jahrbuch*, 1841, p. 8, says of the sand-hills of the Danish coast: "It is not rare to find, high in the knolls, marine shells, and especially those of the oyster. They are due to the oyster-eater [*Hæmatopus ostralegus*], which carries his prey to the top of the dunes to devour it." See also STARING, *De Bodem van Nederland*, i., p. 321.

Human industry has not only fixed the flying dunes by plantations, but, by mixing clay and other tenacious earths with the superficial stratum of extensive sand plains, and by the application of fertilizing substances, it has made them abundantly productive of vegetable life. These latter processes belong to agriculture and not to geography, and, therefore, are not embraced within the scope of the present subject. But the preliminary steps, whereby wastes of loose, drifting barren sands are transformed into wooded knolls and plains, and finally, through the accumulation of vegetable mould, into arable ground, constitute a conquest over nature which precedes agriculture—a geographical revolution—and, therefore, an account of the means by which the change has been effected belongs properly to the history of man's influence on the great features of terrestrial surface. I proceed, then, to examine the structure of dunes, and to describe the warfare man wages with the sand-hills, striving on the one hand to maintain and even extend them, as a natural barrier against encroachments of the sea, and, on the other, to check their moving and wandering propensities, and prevent them from trespassing upon the fields he has planted and the habitations in which he dwells.

Coast Dunes.

Coast dunes are oblong ridges or round hillocks, formed by the action of the wind upon sands thrown up by the waves on the in a continuous, irregular bulwark, but deposited in isolated hillocks, they have a tendency to assume a crescent shape, the convexity being turned seawards, or towards the direction from which the prevailing winds proceed. This fact, the geological bearing of which is obvious, is not noticed by previous French writers or even by Andresen, though a semi-lunar outline has been long generally ascribed to inland dunes. It is, however, evident that such a form would naturally be produced by the action of a wind blowing long in a given direction upon a mass of loose sand with a fixed centre—such as is constituted by the shrub or stone around which the sand is first deposited—and free extremities.

On a receding coast, dunes will not attain so great a height as on more secure shores, because they are undermined and carried off before they have time to reach their greatest dimensions. Hence, while at sheltered points in South-western France, there are dunes three hundred feet or more in height, those on the Frisic Islands and the exposed parts of the coast of Schleswig-Holstein range only from twenty to one hundred feet. On the western shores of Africa, it is said that they sometimes attain an elevation of six hundred feet. This is one of the very few points known to geographers where desert sands are advancing seawards,* and here they rise to the greatest altitude to which sand-grains can be carried by the wind.

The hillocks, once deposited, are held together and kept in shape, partly by mere gravity, and partly by the slight cohesion of the lime, clay, and organic matter mixed with the sand; and it is observed that, from capillary attraction, evaporation from lower strata, and retention of rain-water, they are always moist a little below the surface.† By successive accumulations, they gradually rise to the height of thirty, fifty, sixty, or a hundred feet, and sometimes even much higher. Strong winds, instead of adding to their elevation, sweep off loose particles from their surface, and these, with others blown over or between them, build up a second row of dunes, and so on according to the character of the wind, the supply and consistence of the sand, and the face of the country. In this way is formed a belt of sand-dunes, irregularly dispersed and varying much in height and dimensions, and sometimes many miles in breadth. On the Island of Sylt, in the German Sea, where there are several rows, the width of the belt is from half a mile to a mile. There are similar ranges on the coast of Holland, exceeding two miles

---

* "On the west coast of Africa the dunes are drifting seawards, and always receiving new accessions from the Sahara. They are constantly advancing out into the sea."—NAUMANN, *Geognosie*, ii., p. 1172.

† "Dunes are always full of water, from the action of capillary attraction. Upon the summits, one seldom needs to dig more than a foot to find the

---

sand moist, and in the depressions, fresh water is met with near the surface." —Forchhammer, in Leonhard und Bronn, for 1841, p. 5, note.

On the other hand, Andresen, who has very carefully investigated this as well as all other dune phenomena, maintains that the humidity of the sand ridges cannot be derived from capillary attraction. He found by experiment that a heap of drift-sand was not moistened to a greater height than eight and a half inches, after standing with its base a whole night in water. He states the minimum of water contained by the sand of the dunes, one foot below the surface, after a long drought, at two per cent., the maximum, after a rainy month, at four per cent. At greater depths the quantity is larger. The hygroscopicity of the sand of the coast of Jutland he found to be thirty-three per cent. by measure, or 21.5 by weight. The annual precipitation on that coast is twenty-seven inches, and, as the evaporation is about the same, he argues that rain-water does not penetrate far beneath the surface of the dunes, and concludes that their humidity can be explained only by evaporation from below.—*Om Klitformationen*, pp. 106–110.

In the dunes of Algeria, water is so abundant that wells are constantly dug in them at high points on their surface. They are sunk to the depth of three or four mètres only, and the water rises to the height of a mètre in them.—Laurent, *Mémoire sur le Sahara*, pp. 11, 12, 13.

The same writer observes (p. 14) that the hollows in the dunes are planted with palms which find moisture enough a little below the surface. It would hence seem that the proposal to fix the dunes which are supposed to threaten the Suez Canal, by planting the maritime pine and other trees upon them, is not altogether so absurd as it has been thought to be by some of those disinterested philanthropists of other nations who were distressed with fears that French capitalists would lose the money they had invested in that great undertaking.

Ponds of water are often found in the depressions between the sand-hills of the dune chains in the North American desert.

in breadth, while at the mouths of the Nile they form a zone not less than ten miles wide.

The base of some of the dunes in the Delta of the Nile is reached by the river during the annual inundation, and the infiltration of the water, which contains lime, has converted the lower strata into a silicious limestone, or rather a calcareous sandstone, and thus afforded an opportunity of studying the structure of that rock in a locality where its origin and mode of aggregation and solidification are known.

The tide, though a usual, is by no means a necessary condition for the accumulations of sand out of which dunes are formed. The Baltic and the Mediterranean are almost tideless seas, but there are vast ranges of dunes on the Russian and Prussian coasts of the Baltic and at the mouths of the Nile and many other points on the shores of the Mediterranean. The vast shoals in the latter sea, known to the ancients as the Greater and Lesser Syrtis, are of marine origin. They are still filling up with sand, washed up from greater depths, or sometimes drifted from the coast in small quantities, and will probably be converted, at some future period, into dry land covered with sand-hills. There are also extensive ranges of dunes upon the eastern shores of the Caspian, and at the southern, or rather south-eastern, extremity of Lake Michigan.* There is no doubt that this latter lake formerly extended much farther in that direction, but its southern portion has gradually shoaled and at last been converted into solid land, in consequence of the prevalence of the north-west winds. These blow over the lake a large part of the year, and create a southwardly set of the currents, which wash up sand from the bed of the lake and throw it on shore. Sand is taken up from the beach at Michigan City by every wind from that quarter, and, after a heavy blow of some hours' duration, sand ridges may be observed on the north side of the fences, like the snow wreaths deposited by a drifting wind in winter. Some of the particles are carried back by contrary winds, but most of them lodge on or behind the dunes, or in the moist soil near the lake, or are entangled by vegetables, and tend permanently to elevate the level. Like effects are produced by constant sea-winds, and dunes will generally be formed on all low coasts where such prevail, whether in tideless or in tidal waters.

---

* The careful observations of Colonel J. D. Graham, of the United States Army, show a tide of about three inches in Lake Michigan. See "A Lunar Tidal Wave in the North American Lakes," demonstrated by Lieut.-Colonel J. D. Graham, in the fourteenth volume of the *Proceedings of the American Association for the Advancement of Science.*

Jobard thus describes the *modus operandi*, under ordinary circumstances, at the mouths of the Nile, where a tide can scarcely be detected: "When a wave breaks, it deposits an almost imperceptible line of fine sand. The next wave brings also its contribution, and shoves the preceding line a little higher. As soon as the particles are fairly out of the reach of the water they are dried by the heat of the burning sun, and immediately seized by the wind and rolled or borne farther inland. The gravel is not thrown out by the waves, but rolls backwards and forwards until it is worn down to the state of fine sand, when it, in its turn, is cast upon the land and taken up by the wind." * This description applies only to the common every-day action of wind and water; but just in proportion to the increasing force of the wind and the waves, there is an increase in the quantity of sand, and in the magnitude of the particles carried off from the beach by it, and, of course, every storm in a landward direction adds sensibly to the accumulation upon the shore.

Sand Banks.

Although dunes, properly so called, are found only on dry land and above ordinary high-water mark, and owe their elevation and structure to the action of the wind, yet, upon many shelving coasts, accumulations of sand much resembling dunes are formed under water at some distance from the shore by the oscillations of the waves, and are well known by the name of sand banks. They are usually rather ridges than banks, of moderate inclination, and with the steepest slope seawards,[*] and their form differs little from that of dunes except in this last particular and in being lower and more continuous. Upon the western coast of the island of Amrum, for example, there are three rows of such banks, the summits of which are at a distance of perhaps a couple of miles from each other; so that, including the width of the banks themselves, the spaces between them, and the breadth of the zone of dunes upon the land, the belt of moving sands on that coast is probably not less than eight miles wide.

---

* STARING, *De Bodem van Nederland*, i., p. 327, note.

Under ordinary circumstances, sand banks are always rolling landwards, and they compose the magazine from which the material for the dunes is derived.[†] The dunes, in fact, are but aquatic sand banks transferred to dry land. The laws of their formation are closely analogous, because the action of the two fluids, by which they are respectively accumulated and built up, is very similar when brought to bear upon loose particles of solid matter. It would, indeed, seem that the slow and comparatively regular movements of the heavy, unelastic water ought to affect such particles very differently from the sudden and fitful impulses of the light and elastic air. But the velocity of the wind currents gives them a mechanical force approximating to that of the slower waves, and, however difficult it may be to explain all the phenomena that characterize the structure of the dunes, observation has proved that it is nearly identical with that of submerged sand banks.* The differences of form are generally ascribable to the greater number and variety of surface accidents of the ground on which the sand hills of the land are built up, and to the more frequent changes, and wider variety of direction, in the courses of the wind.

---

[*] KOHL, *Inseln und Marschen Schleswig Holsteins*, ii., p. 33. From a drawing in ANDRESEN, *Om Klitformationen*, p. 24, it would appear that on the Schleswig coast the surf-formed banks have the steepest slope landwards, those farther from the shore, as stated in the text.

[†] Sand banks sometimes connect themselves with the coast at both ends, and thus cut off a portion of the sea. In this case, as well as when salt water is enclosed by sea-dikes, the water thus separated from the ocean gradually becomes fresh, or at least brackish. The Haffs, or large expanses of fresh water in Eastern Prussia—which are divided from the Baltic by narrow sand banks called Nehrungen, or, at sheltered points of the coast, by fluviatile deposits called Werders—all have one or more open passages, through which the water of the rivers that supply them at last finds its way to the sea.

Character of Dune Sand.

"Dune sand," says Staring, "consists of well-rounded grains of quartz, more or less colored by iron, and often mingled with fragments of shells, small indeed, but still visible to the naked eye.† These fragments are not constant constituents of dune

---

* Forchhammer ascribes the resemblance between the furrowing of the dune sands and the beach ripples, not to the similarity of the effect of wind and water upon sand, but wholly to the action of the wind; in the first instance, directly, in the latter, through the water. "The wind-ripples on the surface of the dunes precisely resemble the water-ripples of sand flats occasionally overflowed by the sea; and with the closest scrutiny, I have never been able to detect the slightest difference between them. This is easily explained by the fact, that the water-ripples are produced by the action of light wind on the water which only transmits the air-waves to the sand."—LEONHARD und BRONN, 1841, pp. 7, 8.

† According to the French authorities, the dunes of France are not always composed of quartzose sand. "The dune sands" of different characters, says Brémontier, "partake of the nature of the different materials which compose them. At certain points on the coast of Normandy they are found to be purely calcareous; they are of mixed composition on the shores of Brittany and Saintonge, and generally quartzose between the mouth of the Gironde and that of the Adour."—*Mémoire sur les Dunes, Annales des Ponts et Chaussées*, t. vii., 1833, 1er sémestre, p. 146.

In the dunes of Long Island and of Jutland, there are considerable veins composed almost wholly of garnet. For a very full examination of the mechanical and chemical composition of the dune sands of Jutland, see ANDRESEN, *Om Klitformationen*, p. 110.

Fraas informs us, *Aus dem Orient*, pp. 176, 177, that the dune sands of the Egyptian coast arise from the disintegration of the calcareous sandstone of the same region. This sandstone, composed in a large proportion of detritus of both land and sea shells mingled with quartz sand, appears to have been consolidated under water during an ancient period of subsidence. A later upheaval brought it to or near the surface, when it was more or less disintegrasand. They are sometimes found at the very summits of the hillocks, as at Overveen; in the King's Dune, near Egmond, they form a coarse, calcareous gravel very largely distributed through the sand, while the interior dunes between Haarlem and Warmond exhibit no trace of them. It is yet undecided whether the presence or absence of these fragments is determined by the period of the formation of the dunes, or whether it depends on a difference in the process by which different dunes have been accumulated. Land shells, such as snails, for example, are found on the surface of the dunes in abundance, and many of the shelly fragments in the interior of the hillocks may be derived from the same source."[*]

Sand concretions form within the dunes and especially in the depressions between them. These are sometimes so extensive and impervious as to retain a sufficient supply of water to feed perennial springs, and to form small permanent ponds, and they are a great impediment to the penetration of roots, and consequently to the growth of trees planted, or germinating from self-sown seeds, upon the dunes.[†]

---

ted by the action of the waves and by meteoric influences—a process still going on—and it is now again subsiding with the coast it rests on.

The calcareous sand arising from the comminution of corals forms dunes on some of the West India Islands.—Agassiz, *Bulletin of the Museum of Comparative Zoölogy*, vol. i.

[*] *De Bodem van Nederland*, i., p. 323.

[†] Staring, *De Bodem van Nederland*, i., p. 317. See also Bergsöe, *Reventlov's Virksomhed*, ii., p. 11.

"In the sand-hill ponds mentioned in the text, there is vigorous growth of bog plants accompanied with the formation of peat, which goes on regularly as long as the dune sand does not drift. But if the surface of the dunes is broken, the sand blows into the ponds, covers the peat, and puts an end to its formation. When, in the course of time, marine currents cut away the coast, the dunes move landwards and fill up the ponds, and thus are formed the remarkable strata of fossile peat called Martörv, which appears to be unknown to the geologists of other parts of Europe."—Forchhammer, in Leonhard und Bronn, 1841, p. 13. Martörv has a specific gravity thrice as great as that of ordinary peat in consequence of the pressure of the sand —Asbjörnsen, *Torv og Torvdrift*, p. 26.

Interior Structure of Dunes.

The interior structure of the dunes, the arrangement of their particles, is not, as might be expected, that of an unorganized, confused heap, but they show a strong tendency to stratification. This is a point of much geological interest, because it indicates that sandstone may owe its stratified character to the action of other forces as well as of water. The origin and peculiar character of these layers are due to a variety of causes.

For example, a south-west wind and current may deposit upon a dune a stratum of a given color and mineral composition, and this may be succeeded by a north-west wind and current, bringing with them particles of a different hue, constitution, and origin. Again, if we suppose a violent tempest to strew the beach with sand-grains very different in magnitude and specific gravity, and, after the sand is dry, to be succeeded by a gentle breeze, it is evident that only the lighter particles will be taken up and carried to the dunes. If, after some time, the wind freshens, heavier grains will be transported and deposited on the former, and a still stronger succeeding gale will roll up yet larger kernels. Each of these deposits will form a stratum. If we suppose the tempest to be followed, after the sand is dry, not by a gentle breeze, but by a wind powerful enough to lift at the same time particles of very various magnitudes and weights, the heaviest will often lodge on the dune while the lighter will be carried farther. This would produce a stratum of coarse sand, and the same effect might result from the blowing away of light particles out of a mixed layer, while the heavier remained undisturbed.* Still another cause of apparent stratification may be found in the occasional interpo-

---

* The lower strata must be older than the superficial layers, and the particles which compose them may in time become more disintegrated, and therefore finer than those deposited later and above them.

Hull ingeniously suggests that, besides other changes, fine sand intermixed with or deposited above a coarser stratum, as well as the minute particles sition of a thin layer of leaves or other vegetable remains between successive deposits, and this I imagine to be more frequent than has been generally supposed. Some geologists have thought that the sand strata of dunes are of annual formation;[*] but the autumnal deposit of foliage from neighboring trees and shrubs furnishes a more probable explanation of the division of the sand-heaps into regular layers.

A late distinguished American admiral communicated to me an interesting observation made by him at San Francisco, which has an important bearing on the arrangement of the particles of sand in dunes and other irregular accumulations of that substance. In laying out a navy-yard at that port, a large quantity of earthy material was removed from the dunes and other hillocks and carted to a low piece of ground which required filling up. Sand of various characters, fine and coarse gravel, and common earth were dropped promiscuously by the carts as accident or convenience dictated, and of course they were all confusedly intermixed. Some time after, when the new ground was consolidated, various excavations were made in it, and the different materials of which the filling was composed were found to be stratified with considerable regularity, according to their specific gravity.

Two explanations of this remarkable fact suggest themselves to me, which, however, do not perhaps exclude others. San Francisco is subject to earthquakes, and though violent or even sensible shocks are not very frequent, it is highly probable that, as is shown to be the case in many other countries, by late seismological observations, there are, in the course of the year, a great number of slight shocks which escape unscientific observation. A frequent repetition of slight tremblings of the earth

---

resulting from the disintegration of the grains of the latter, may be carried by rain in the case of dunes, or by the ordinary action of sea-water in that of sand-banks, down through the interstices in the coarser layer, and thus the relative position of sand and gravel may be changed.—*Oorsprong der Hollandsche Duinen*, p. 103.

[*] SCHOMANN, *Geologische Wanderungen durch die Preussischen Ost-See Provinzen*, 1869, p. 81.

would, like any other moderate mechanical agitation, probably produce the separation of a miscellaneous mass, like that described, into distinct layers. Again, the Pacific coast, like all others upon an open sea, is exposed to incessant concussion from the shock of the waves, which is repeated many thousand times a day. This concussion is often sensibly felt by the observer, and it seems not in the least improbable that the agitation may have tended to produce a stratified arrangement in the case at San Francisco, as well as in all coast dunes and other accumulations of loose mineral material in similar situations. Kohl observes that the shore on the landward side of the files of dunes often trembles from the shock of the waves on the beach,* and Villeneuve established by careful experiment that at Dunkerque the ground is sensibly agitated by the same cause, in stormy weather, to a distance of more than a mile from the sea.

The eddies of strong winds between the hillocks must also occasion disturbances and re-arrangements of the sand layers, and it seems possible that the irregular thickness and the strange contortions of the strata of the sandstone at Petra may be due to some such cause. A curious observation of Professor Forchhammer suggests an explanation of another peculiarity in the structure of the sandstone of Mount Seir. He describes dunes in Jutland, composed of yellow quartzose sand intermixed with black titanian iron. When the wind blows over the surface of the dunes, it furrows the sand with alternate ridges and depressions, ripples, in short, like those of water. The swells, the dividing ridges of the system of sand ripples, are composed of the light grains of quartz, while the heavier iron rolls into the depressions between, and thus the whole surface of the dune appears as if covered with a fine black network.

The sea side of dunes, being more exposed to the caprices of the wind, is more irregular in form than the lee or land side, where the arrangement of the particles is affected by fewer disturbing and conflicting influences. Hence, the stratification of the windward slope is somewhat confused, while the sand on the lee side is found to be disposed in more regular beds, inclining landwards, and with the largest particles lowest, where their greater weight would naturally carry them. The lee side of the dunes, being thus formed of sand deposited according to the laws of gravity, is very uniform in its slope, which, according to Forchhammer, varies little from an angle of 30° with the horizon, while the more exposed and irregular weather side lies at an inclination of from 5° to 10°. When, however, the outer tier of dunes is formed so near the water-line as to be exposed to the immediate action of the waves, it is undermined, and the face of the hill is very steep and sometimes nearly perpendicular.

---

* *Inseln und Marschen*, etc., ii., p. 34.

Geological Importance of Dunes.

These observations, and other facts which a more attentive study on the spot would detect, might furnish the means of determining interesting and important questions concerning geological formations in localities very unlike those where dunes are now thrown up. For example, Studer supposes that the drifting sand-hills of the African desert were originally coast dunes, and that they have been transported to their present position far in the interior, by the rolling and shifting leeward movement to which all dunes not covered with vegetation are subject. The present general drift of the sands of that desert appears to be to the south-west and west, the prevailing winds blowing from the north-east and east; but it has been doubted whether the shoals of the western coast of Northern Africa, and the sands upon that shore, are derived from the bottom of the Atlantic, in the usual manner, or, by an inverse process, from those of the Sahara. The latter, as has been before remarked, is probably the truth, though observations are wanting to decide the question.* There would be nothing violently improbable in the *a priori* supposition that they may have been in part first thrown up by the Mediterranean on its Libyan coast, and thence blown south and west over the vast space they now cover. But inasmuch as it is now geologically certain that the Sahara is an uplifted bed of an ancient sea, we may suppose that, while submerged, it was, like other sea-bottoms, strewn with sand, and that its present supply of that material was, in great proportion, brought up with it. Laurent observed, some years ago, that marine shells of still extant species were found in the Sahara, far from the sea, and even at considerable depths below the surface.[*] These observations have been confirmed past all question by Desor, Martins, and others, and the facts and the obvious conclusion they suggest are at present not disputed.

---

* "The North African desert falls into two divisions: the Sahel, or western, and the Sahar, or eastern. The sands of the Sahar were, at a remote period,

But whatever has been the source and movement of these sands, they can hardly fail to have left on their route some sandstone monuments to mark their progress, such, for example, as we have seen are formed from the dune sand at the mouth of the Nile; and it is conceivable that the character of the drifting sands themselves, and of the conglomerates and sandstones to whose formation they have contributed, might furnish satisfactory evidence as to their origin, their starting-point, and the course by which they have wandered so far from the sea.[†]

---

drifted to the west. In the Sahel, the prevailing east winds drive the sand-ocean with a progressive westward motion. The eastern half of the desert is swept clean."—NAUMANN, *Geognosie*, ii., p. 1173.

[*] *Mêmoires sur le Sahara Oriental* p. 62.

[†] Forchhammer, after pointing out the coincidence between the inclined stratification of dunes and the structure of ancient tilted rocks, says: "But I am not able to point out a sandstone formation corresponding to the dunes. Probably most ancient dunes have been destroyed by submersion before the loose sand became cemented to solid stone, but we may suppose that circumstances have existed somewhere which have preserved the characteristics of this formation."—LEONHARD und BRONN, 1841, p. 8, 9.

Such formations, however, certainly exist. Laurent (*Mèmoire sur le Sahara, etc.*, p. 12) tells us that in the Algerian desert there are "sandstone formation" not only "corresponding to the dunes," but actually consolidated within them. "A place called El-Mouia-Tadjer presents a repetition of what we saw at El-Baya; one of the funnels formed in the middle of the dunes contains wells from two mètres to two and a half in depth, dug in a sand which pressure, If the sand of coast dunes is, as Staring describes it, composed chiefly of well-rounded quartzose grains, fragments of shells, and other constant ingredients, it would often be recognizable as coast sand, in its agglutinate state of sandstone. The texture of this rock varies from an almost imperceptible fineness of grain to great coarseness, and affords good facilities for microscopic observation of its structure. There are sandstones, such, for example, as are used for grindstones, where the grit, as it is called, is of exceeding sharpness; others where the angles of the grains are so obtuse that they scarcely act at all on hard metals. The former may be composed of grains of rock, disintegrated indeed, and re-cemented together, but not, in the meanwhile, much rolled; the latter, of sands long washed by the sea, and drifted by land-winds. There is, indeed, so much resemblance between the effects of driving winds and of rolling water upon light bodies, that there might be difficulty in distinguishing them; but after all, it is not probable that sandstone, composed of grains thrown up from the salt sea, and long tossed by the winds, would be identical in its structure with that formed from fragments of rock crushed by mechanical force, or disintegrated by heat, and again agglutinated without much exposure to the action of moving water.

---

and probably the presence of certain salts, have cemented so as to form true sandstone, soft indeed, but which does not yield except to the pickaxe. These sandstones exhibit an inclination which seems to be the effect of wind; for they conform to the direction of the sands which roll down a scarp occasioned by the primitive obstacle."

"At New Quay the dune sands are converted to stone by an oxide of iron held in solution by the water which pervades them. This stone, which is formed, so to speak, under our eye, has been found solid enough to be employed for building."—ESQUIROS, *L'Angleterre, etc., in Revue des Deux Mondes*, 1864, pp. 44, 45.

The dunes near the mouth of the Nile, the lower sands of which have been cemented together by the infiltration of Nile water, would probably show a similar stratification in the sandstone which now forms their base.

Dana describes a laminated rock often formed by the infiltration of water into the sand dunes on the Hawaian islands.—*Corals and Coral Islands*, 1872, p. 155.

Dunes of American Coasts.

Upon the Atlantic coast of the United States, the prevalence of western or off-shore winds is unfavorable to the formation of dunes, and, though marine currents lodge vast quantities of sand, in the form of banks, on that coast, its shores are proportionally more free from sand-hills than some others of lesser extent. There are, however, very important exceptions. The action of the tide throws much sand upon some points of the New England coast, as well as upon the beaches of Long Island and other more southern shores, and here dunes resembling those of Europe are formed. There are also extensive ranges of dunes on the Pacific coast of the United States, and at San Francisco they border some of the streets of the city.

The dunes of America are far older than her civilization, and the soil they threaten or protect possesses, in general, too little value to justify any great expenditure in measures for arresting their progress or preventing their destruction. Hence, great as is their extent and their geographical importance, they have, at present, no such intimate relations to human life as to render them objects of special interest in the point of view I am taking, and I do not know that the laws of their formation and motion have been made a subject of original investigation by any American observer.

Dunes of Western Europe.

Upon the western coast of Europe, on the contrary, the ravages occasioned by the movement of sand dunes, and the serious consequences often resulting from the destruction of them, have long engaged the earnest attention of Governments and of scientific men, and for nearly a century persevering and systematic effort has been made to bring them under human control. The subject has been carefully studied in Denmark and the adjacent duchies, in Western Prussia, in the Netherlands, and in France; and the experiments in the way of arresting the drifting of the dunes, and of securing them, and the lands they shelter, from the encroachments of the sea, have resulted in the adoption of a system of coast improvement substantially the same in all these countries. The sands, like the forests, have now their special literature, and the volumes and memoirs, which describe them and the processes employed to subdue them, are full of scientific interest and of practical instruction.

Dunes of Gascony.

In the small kingdom of Denmark, inclusive of the duchies of Schleswig and Holstein, the dunes cover an area of more than two hundred and sixty square miles. The breadth of the chain is very various, and in some places it consists only of a single row of sand-hills, while in others, it is more than six miles wide.* The dunes of the Prussian coast are vaguely estimated to cover from eighty-five to one hundred and ten thousand acres; those of Holland one hundred and forty thousand acres; and those of Gascony more than two hundred thousand acres. I do not find any estimate of their extent in other provinces of France, or in the Baltic provinces of Russia, but it is probable that the entire quantity of dune land upon the Atlantic and Baltic shores of Europe does not fall much short of a million of acres.† This vast deposit of sea-sand extends along the coasts for a distance of several hundred miles, and from the time of the destruction of the forests which covered it, to the year 1789, the whole line was rolling inwards and burying the soil beneath it, or rendering the fields unproductive by the sand which drifted from it. At the same time, as the sand-hills moved landwards, the ocean was closely following their retreat and swallowing up the ground they had covered, as fast as their movement left it bare.

---

* ANDERSEN, *Om Klitformationen*, pp. 78, 262, 275.

† In an article on the dunes of Europe. in vol. 29 (1864) of *Aus der Natur*, p. 590, the dunes are estimated to cover, on the islands and coasts of Schleswig Holstein, in North-west Germany, Denmark, Holland, and France, one hundred and eighty-one German, or nearly four thousand English square miles; in Scotland, about ten German, or two hundred and ten English miles; in Ireland, twenty German, or four hundred and twenty English miles; and in England, one hundred and twenty German, or more than twenty-five hundred English miles. Pannewitz (*Anleitung zum Anbau der Sandflächen*), as cited by Andresen (*Om Klitformationen*, p. 45), states that the drifting sands of Europe, including, of course, sand plains as well as dunes, cover an extent of 21,000 square miles. This is, perhaps, an exaggeration, though there is,

Age, Character, and Permanence of Dunes.

The origin of most great lines of dunes goes back past all history. There are on many coasts several distinct ranges of sand-hills which seem to be of very different ages, and to have been formed under different relative conditions of land and water.* In some cases there has been an upheaval of the coast line since the formation of the oldest hillocks, and these have

---

undoubtedly, much more desert-land of this description on the European continent than has been generally supposed. There is no question that most of this waste is capable of reclamation by simple planting, and no mode of physical improvement is better worth the attention of civilized Governments than this.

There are often serious objections to extensive forest planting on soils capable of being otherwise made productive, but they do not apply to sand wastes, which, until covered by woods, are not only a useless incumbrance, but a source of serious danger to all human improvements in the neighborhood of them.

* Krause, speaking of the dunes on the coast of Prussia, says: "Their origin belongs to three different periods, in which important changes in the relative level of sea and land have unquestionably taken place. . . . Except in the deep depressions between them, the dunes are everywhere sprinkled, to a considerable height, with brown oxydulated iron, which has penetrated into the sand to the depth of from three to eighteen inches, and colored it red. . . . Above the iron is a stratum of sand differing in composition from ordinary sea-sand, and on this, growing woods are always found. . . . The gradually accumulated forest soil occurs in beds of from one to three feet thick, and changes, proceeding upward, from gray sand to black humus." Even on the third or seaward range, the sand grasses appear and thrive luxuriantly, at least on the west coast, though Krause doubts whether the dunes of the east coast were ever thus protected.—*Der Dünenbau*, pp. 8, 11.

become inland dunes, while younger rows have been thrown up on the new beach laid bare by elevation of the sea-bed. Our knowledge of the mode of their first accumulation is derived from observation of the action of wind and water in the few instances where, with or without the aid of man, new coast dunes have been accumulated, and of the influence of wind alone in elevating new sand-heaps inland of the coast tier, when the outer rows are destroyed by the sea, as also when the sodded surface of ancient sands has been broken, and the subjacent strata laid open to the air.

It is a question of much interest, in what degree the naked condition of most dunes is to be ascribed to the improvidence and indiscretion of man. There are, in Western France, extensive ranges of dunes covered with ancient and dense forests, while the recently formed sand-hills between them and the sea are bare of vegetation, and in some cases are rapidly advancing upon the wooded dunes, which they threaten to bury beneath their drifts. Between the old dunes and the new there is no discoverable difference in material or in structure; but the modern sand-hills are naked and shifting, the ancient, clothed with vegetation and fixed. It has been conjectured that artificial methods of confinement and plantation were employed by the primitive inhabitants of Gaul; and Laval, basing his calculations on the rate of annual movement of the shifting dunes, assigns the fifth century of the Christian era as the period when these processes were abandoned.*

There is no historical evidence that the Gauls were acquainted with artificial methods of fixing the sands of the coast, and we have little reason to suppose that they were advanced enough in civilization to be likely to resort to such processes, especially at a period when land could have had but a moderate value.

In other countries, dunes have spontaneously clothed themselves with forests, and the rapidity with which their surface is covered by various species of sand-plants, and finally by trees, where man and cattle and burrowing animals are excluded from them, renders it highly probable that they would, as a general rule, protect themselves, if left to the undisturbed action of natural causes. The sand-hills of the Frische Nehrung, on the coast of Prussia, were formerly wooded down to the water's edge, and it was only in the last century that, in consequence of the destruction of their forests, they became moving sands.[*] There is every reason to believe that the dunes of the Netherlands were clothed with trees until after the Roman invasion. The old geographers, in describing these countries, speak of vast forests extending to the very brink of the sea; but drifting coast dunes are first mentioned by the chroniclers of the Middle Ages, and so far as we know they have assumed a destructive character in consequence of the improvidence of man.[†] The history of the dunes of Michigan, so far as I have been able to learn from my own observation, or that of others, is the same. Thirty years ago, when that region was scarcely inhabited, they were generally covered with a thick growth of trees, chiefly pines, and underwood, and there was little appearance of undermining and wash on the lake side, or of shifting of the sands, except where the trees had been cut or turned up by the roots.*

---

* LAVAL, *Mémoire sur les Dunes de Gascogne*, *Annales des Ponts et Chaussées*, 1847, 2me sémestre, p. 231. The same opinion had been expressed by BRÉMONTIER, *Annales des Ponts et Chaussées*, 1833, 1er sémestre, p. 185.

---

[*] "In the Middle Ages," says Willibald Alexis, as quoted by Müller, *Das Buch der Pflanzenwelt*, i., p. 16, "the Nehrung was extending itself further, and the narrow opening near Lochstadt had filled itself up with sand. A great pine forest bound with its roots the dune sand and the heath uninterruptedly from Danzig to Pillau. King Frederick William I. was once in want of money. A certain Herr von Korff promised to procure it for him, without loan or taxes, if he could be allowed to remove something quite useless. He thinned out the forests of Prussia, which then, indeed, possessed little pecuniary value; but he felled the entire woods of the Frische Nehrung, so far as they lay within the Prussian territory. The financial operation was a success. The king had money, but in the material effects which resulted from it, the state received irreparable injury. The sea-winds rush over the bared hills; the Frische Haff is half-choked with sand; the channel between Elbing, the sea, and Königsberg is endangered, and the fisheries in the Haff injured. The operation of Herr von Korff brought the king 200,000 thalers. The state would now willingly expend millions to restore the forests again."

[†] STARING, *Voormaals en Thans*, p. 231. Had the dunes of the Netherlandish and French coasts, at the period of the Roman invasion, resembled the moving sand-hills of the present day, it is inconceivable that they could have escaped the notice of so acute a physical geographer as Strabo; and the absolute silence of Cæsar, Ptolemy, and the encyclopædic Pliny, respecting them, would be not less inexplicable.

Nature, as she builds up dunes for the protection of the seashore, provides, with similar conservatism, for the preservation of the dunes themselves; so that, without the interference of man, these hillocks would be, not perhaps absolutely perpetual, but very lasting in duration, and very slowly altered in form or position. When once covered with the trees, shrubs, and herbaceous growths adapted to such localities, dunes undergo no apparent change, except the slow occasional undermining of the outer tier, and accidental destruction by the exposure of the interior, from the burrowing of animals, or the upturning of trees with their roots, and all these causes of displacement are very much less destructive when a vegetable covering exists in the immediate neighborhood of the breach.

Protection of Dunes.

Before the occupation of the coasts by man, dunes, at all points where they have been observed, seem to have been protected in their rear by forests, which served to break the force of the winds in both directions,* and to have spontaneously clothed themselves with a dense growth of the various plants, grasses, shrubs, and trees, which nature has assigned to such soils. It is observed in Europe that dunes, though now without the shelter of a forest country behind them, begin to protect themselves as soon as human trespassers are excluded, and grazing animals denied access to them. Herbaceous and arborescent plants spring up almost at once, first in the depressions, and then upon the surface of the sand-hills. Every seed that sprouts, binds together a certain amount of sand by its roots, shades a little ground with its leaves, and furnishes food and shelter for still younger or smaller growths. A succession of a very few favorable seasons suffices to bind the whole surface together with a vegetable network, and the power of resistance possessed by the dunes themselves, and the protection they afford to the fields behind them, are just in proportion to the abundance and density of the plants they support.

---

* The sands of Cape Cod were partially, if not completely, covered with vegetation by nature. Dr. Dwight, describing the dunes as they were in 1800, says: "Some of them are covered with beach grass; some fringed with whortleberry bushes; and some tufted with a small and singular growth of oaks. . . . The parts of this barrier which are covered with whortleberry bushes and with oaks, have been either not at all or very little blown. The oaks, particularly, appear to be the continuation of the forests originally formed on this spot. . . . They wore all the marks of extreme age; were, in some instances, already decayed, and in others decaying; were hoary with moss, and were deformed by branches, broken and wasted, not by violence, but by time."—*Travels*, iii., p. 91.

The growth of the vegetable covering can, of course, be much accelerated by judicious planting and watchful care, and this species of improvement is now carried on upon a vast scale on the sandy coasts of Western Europe, wherever the value of land is considerable and the population dense.

Use of Dunes as a Barrier against the Sea.

Although the sea throws up large quantities of sand on flat lee-shores, there are many cases where it continually encroaches on those same shores and washes them away. At all points of the shallow North Sea where the agitation of the waves extends to the bottom, banks are forming and rolling eastwards. Hence the sea-sand tends to accumulate upon the coast of Schleswig-Holstein and Jutland, and were there no conflicting influences, the shore would rapidly extend itself westwards. But the same waves which wash the sand to the coast undermine the beach they cover, and still more rapidly degrade the shore at points where it is too high to receive partial protection by the formation of dunes upon it. The earth of the coast is generally composed of particles finer, lighter, and more transportable by water than the sea-sand. While, therefore, the billows raised by a heavy west wind may roll up and deposit along the beach thousands of tons of sand, the same waves may swallow up even a larger quantity of fine shore-earth. This earth, with a portion of the sand, is swept off by northwardly and southwardly currents, and let fall at other points of the coast, or carried off, altogether, out of the reach of causes which might bring it back to its former position.

---

* Bergsöe (*Reventlovs Virksomhed*, ii., 3) states that the dunes on the west coast of Jutland were stationary before the destruction of the forests to the east of them. The felling of the tall trees removed the resistance to the lower currents of the westerly winds, and the sands have since buried a great extent of fertile soil. See also same work, ii., p. 124.

Although, then, the eastern shore of the German Ocean here and there advances into the sea, it in general retreats before it, and but for the protection afforded it by natural arrangements seconded by the art and industry of man, whole provinces would soon be engulfed by the waters. This protection consists in an almost unbroken chain of sand banks and dunes, extending from the northernmost point of Jutland to the Elbe, a distance of not much less than three hundred miles, and from the Elbe again, though with more frequent and wider interruptions, to the Atlantic borders of France and Spain. So long as the dunes are maintained by nature or by human art, they serve, like any other embankment or dike, as a partial or a complete protection against the encroachments of the sea; and on the other hand, when their drifts are not checked by natural processes, or by the industry of man, they become a cause of as certain, if not of as sudden, destruction as the ocean itself whose advance they retard. On the whole, the dunes on the coast of the German Sea, notwithstanding the great quantity of often fertile land they cover, and the evils which result from their movement, are a protective and beneficial agent, and their maintenance is an object of solicitude with the Governments and people of the shores they defend.[*]

The eastward progress of the sea on the Danish, Netherlandish, and French coasts depends so much on local geological structure, on the force and direction of tidal and other marine currents, on the volume and rapidity of coast rivers, on the contingencies of the weather and on other varying circumstances, that no general rate can be assigned to it.

At Agger, near the western end of the Liimfjord, in Jutland, the coast was washed away, between the years 1815 and 1839, at the rate of more than eighteen feet a year. The advance of the sea appears to have been something less rapid for a century before; but from 1840 to 1857, it gained upon the land no less than thirty feet a year. At other points of the shore of Jutland the loss is smaller, but the sea is encroaching generally upon the whole line of the coast.[†]

The Liimfjord.

The irruption of the sea into the fresh-water lagoon of Liimfjord in Jutland, in 1825—one of the most remarkable encroachments of the ocean in modern times—is expressly ascribed to "mismanagement of the dunes" on the narrow neck of land which separated the fjord from the North Sea. At earlier periods the sea had swept across the isthmus, and even burst through it, but the channel had been filled up again,

---

[*] "We must, therefore, not be surprised to see the people here deal as gingerly with their dunes as if treading among eggs. He who is lucky enough to own a molehill of dune pets it affectionately, and spends his substance in cherishing and fattening it. That fair, fertile, rich province, the peninsula of Eiderstädt in the south of Friesland, has, on the point towards the sea, only a tiny row of dunes, some six miles long or so; but the people talk of their fringe of sand hills, as if it were a border set with pearls. They look upon it as their best defence against Neptune. They have connected it with their system of dikes, and for years have kept sentries posted to protect it against wanton injury."—J. G. KOHL, *Die Inseln u. Marschen Schleswig-Holsteins*, ii., p. 115.

[†] ANDRESEN, *Om Klitformationen*, pp. 68–72.

Coasts of Schleswig-Holstein, Holland, and France.

On the islands on the coast of Schleswig-Holstein, the advance of the sea has been more unequivocal and more rapid. Near the beginning of the last century, the dunes which had protected the western coast of the island of Sylt began to roll to the east, and the sea followed closely as they retired. In 1757, the church of Rantum, a village upon that island, was obliged to be taken down in consequence of the advance of the sand-hills; in 1791, these hills had passed beyond its site, the waves had swallowed up its foundations, and the sea gained so rapidly, that, fifty years later, the spot where they lay was seven hundred feet from the shore.*

The most prominent geological landmark on the coast of Holland is the Huis te Britten, *Arx Britannica*, a fortress built by the Romans, in the time of Caligula, on the main land near the mouth of the Rhine. At the close of the seventeenth century, the sea had advanced sixteen hundred paces beyond it. The older Dutch annalists record, with much parade of numerical accuracy, frequent encroachments of the sea upon many parts of the Netherlandish coast. But though the general fact of an advance of the ocean upon the land is established beyond dispute, the precision of the measurements which have been given is open to question. Staring, however, who thinks the erosion of the coast much exaggerated by popular geographers, admits a loss of more than a million and a half acres, chiefly worthless morass; † and it is certain that but for the resistance of man, but for his erection of dikes and protection of dunes, there would now be left of Holland little but the name. It is, as has been already seen, still a debated question among geologists whether the coast of Holland now is, and for centuries has been, subsiding. I believe most investigators maintain the affirmative; and if the fact is so, the advance of the sea upon the land is, in part, due to this cause. But the rate of subsidence is at all events very small, and therefore the encroachments of the ocean upon the coast are mainly to be ascribed to the erosion and transportation of the soil by marine waves and currents.

---

* ANDRESEN, *Om Klitformationen*, pp. 68, 72.

† *Voormaals en Thans*, pp. 126, 170.

The sea is fast advancing at several points of the western coast of France, and unknown causes have given a new impulse to its ravages since the commencement of the present century. Between 1830 and 1842, the Point de Grave, on the north side of the Gironde, retreated one hundred and eighty mètres, or fifty feet per year; from the latter year to 1846, the rate was increased to more than three times that quantity, and the loss in those four years was about six hundred feet. All the buildings at the extremity of the peninsula have been taken down and rebuilt farther landwards, and the lighthouse of the Grave now occupies its third position. The sea attacked the base of the peninsula also, and the Point de Grave and the adjacent coasts have been for thirty years the scene of one of the most obstinately contested struggles between man and the ocean recorded in the annals of modern engineering.

Movement of Dunes.

Besides their importance as a barrier against the inroads of the ocean, dunes are useful by sheltering the cultivated ground behind them from the violence of the sea-wind, from salt spray, and from the drifts of beach sand which would otherwise overwhelm them. But the dunes themselves, unless their surface sands are kept moist, and confined by the growth of plants, or at least by a crust of vegetable earth, are constantly rolling inwards, and thus, while, on one side, they lay bare the traces of ancient human habitations or other evidences of the social life of primitive man, they are, on the other, burying fields, houses, churches, and converting populous districts into barren and deserted wastes.

Especially destructive are they when, by any accident, a cavity is opened into them to a considerable depth, thereby giving the wind access to the interior, where the sand is thus first dried, and then scooped out and scattered far over the neighboring soil The dune is now a magazine of sand, no longer a rampart against it, and mischief from this source seems more difficult to resist than from almost any other drift, because the supply of material at the command of the wind is more abundant and more concentrated than in its original thin and widespread deposits on the beach. The burrowing of conies in the dunes is, in this way, not unfrequently a cause of their destruction and of great injury to the fields behind them. Drifts, and even inland sand-hills, sometimes result from breaking the surface of more level sand deposits, far within the range of the coast dunes. Thus we learn from Staring, that one of the highest inland dunes in Friesland owes its origin to the opening of the drift sand by the uprooting of a large oak.*

Great as are the ravages produced by the encroachment of the sea upon the western shores of continental Europe, they have been in some degree compensated by spontaneous marine deposits at other points of the coast, and we have seen in a former chapter that the industry of man has reclaimed a large territory from the bosom of the ocean. These latter triumphs are not of recent origin, and the incipient victories which paved the way for them date back perhaps as far as ten centuries. In the meantime, the dunes had been left to the operation of the laws of nature, or rather freed, by human imprudence, from the fetters with which nature had bound them, and it is scarcely three generations since man first attempted to check their destructive movements. As they advanced, he unresistingly yielded and retreated before them, and they have buried under their sandy billows many hundreds of square miles of luxuriant cornfields and vineyards and forests.

On the west coast of France a belt of dunes, varying in width from a quarter of a mile to five miles, extends from the Adour to the estuary of the Gironde, and covers an area of nine hundred and seventy square kilomètres, or two hundred and forty thousand acres. When not fixed by vegetable growths, these dunes advance eastwards at a mean rate of about one rod, or sixteen and a half feet, a year. We do not know historically when they began to drift, but if we suppose their motion to have been always the same as at present, they would have passed over the space between the sea coast and their present eastern border, and covered the large area above mentioned, in fourteen hundred years. We know, from written records, that they have buried extensive fields and forests and thriving villages, and changed the courses of rivers, and that the lighter particles carried from them by the winds, even where not transported in sufficient quantities to form sand-hills, have rendered sterile much land formerly fertile.[*] They have also injuriously obstructed the natural drainage of the maritime districts by choking up the beds of the streams, and forming lakes and pestilential swamps of no inconsiderable extent. In fact, so completely do they embank the coast, that between the Gironde and the village of Mimizan, a distance of one hundred miles, there are but two outlets for the discharge of all the waters which flow from the land to the sea; and the eastern front of the dunes is bordered by a succession of stagnant pools, some of which are more than six miles in length and breadth.[†]

---

* *De Bodem van Nederland*, i., p. 425.

---

[*] The movement of the dunes has been hardly less destructive on the north side of the Gironde. See the valuable articles of ÉLISÉE RECLUS in the *Revue des Deux Mondes* for December, 1862, and several later numbers, entitled "*Le Littoral de la France.*"

[†] LAVAL, *Mémoire sur les Dunes du Golfe de Gascogne*, *Annales des Ponts et Chaussées*, 1847, p. 223. The author adds, as a curious and unexplained fact, that some of these pools, though evidently not original formations but mere accumulations of water dammed up by the dunes, have, along their western shore, near the base of the sand-hills, a depth of more than one hundred and thirty feet, and hence their bottoms are not less than eighty feet below the level of the lowest tides. Their western banks descend steeply,

A range of dunes extends along the whole western coast of Jutland and Schleswig-Holstein, and the movement of these sand-hills was formerly, and at some points still is, very destructive. The rate of eastward movement of the drifting dunes varies from three to twenty-four feet per annum. If we adopt the mean of thirteen feet and a half for the annual motion, these dunes have traversed the widest part of the belt in about twenty-five hundred years. Historical data are wanting as to the period of the formation of these dunes and of the commencement of their drifting; but there is recorded evidence that they have buried a vast extent of valuable land within three or four centuries, and further proof is found in the fact that the movement of the sands is constantly uncovering ruins of ancient buildings, and other evidences of human occupation, at points far within the present limits of the uninhabitable desert. Andresen estimates the average depth of the sand deposited over this area at thirty feet, which would give a cubic mile and a half for the total quantity.*

The drifting of the dunes on the coast of Prussia commenced not much more than a hundred years ago. The Frische Nehrung is separated from the mainland by the Frische Haff, and there is but a narrow strip of arable land along its eastern borders. Hence its rolling sands have covered a comparatively small extent of dry land, but fields and villages have been buried and valuable forests laid waste by them. The loose

---

conforming nearly to the slope of the dunes, while on the north-east and south the inclination of their beds is very gradual. The greatest depth of these pools corresponds to that of the sea ten miles from the shore. Is it possible that the weight of the sands has pressed together the soil on which they rest, and thus occasioned a subsidence of the surface extending beyond their base?

A more probable explanation of the fact stated in the note is suggested by Élisée Reclus, in an article entitled *Le Littoral de la France*, in the *Revue des Deux Mondes* for September 1, 1864, pp. 193, 194. This able writer believes such pools to be the remains of ancient maritime bays, which have been cut off from the ocean by gradually accumulated sand banks raised by the waves and winds to the character of dunes.

* ANDRESEN, *Om Klitformationen*, pp. 56, 79, 82.

coast-row has drifted over the inland ranges, which, as was noticed in the description of these dunes on a former page, were protected by a surface of different composition, and the sand has thus been raised to a height which it could not have reached upon level ground. This elevation has enabled it to advance upon and overwhelm woods, which, upon a plain, would have checked its progress, and, in one instance, a forest of many hundred acres of tall pines was destroyed by the drifts between 1804 and 1827.

Control of Dunes by Man.

There are three principal modes in which the industry of man is brought to bear upon the dunes. First, the creation of them, at points where, from changes in the currents or other causes, new encroachments of the sea are threatened; second, the maintenance and protection of them where they have been naturally formed; and third, the removal of the inner rows where the belt is so broad that no danger is to be apprehended from the loss of them.

In describing the natural formation of dunes, it was said that they began with an accumulation of sand around some vegetable or other accidental obstruction to the drifting of the particles. A high, perpendicular cliff, which deadens the wind altogether, prevents all accumulation of sand; but, up to a certain point, the higher and broader the obstruction, the more sand will heap up in front of it, and the more will that which falls behind it be protected from drifting farther. This familiar observation has taught the inhabitants of the coast that an artificial wall or dike will, in many situations, give rise to a broad belt of dunes. Thus a sand dike or wall, of three or four miles in length, thrown in 1610 across the Koegras, a tide-washed flat between the Zuiderzee and the North Sea, has occasioned the formation of rows of dunes a mile in breadth, and thus excluded the sea altogether from the Koegras. A similar dike, called the Zijperzeedijk, has produced another scarcely less extensive belt in the course of two centuries.

A few years since, the sea was threatening to cut through the island of Ameland, and, by encroachment on the southern side and the blowing off of the sand from a low flat which connected the two higher parts of the island, it had made such progress, that in heavy storms the waves sometimes rolled quite across the isthmus. The construction of a breakwater and a sand dike have already checked the advance of the sea, and a large number of sand-hills has been formed, the rapid growth of which promises complete future security against both wind and wave. Similar effects have been produced by the erection of plank fences, and even of simple screens of wattling and reeds.*

The dunes of Holland are sometimes protected from the dashing of the waves by a *revêtement* of stone, or by piles; and the lateral high-water currents, which wash away their base, are occasionally checked by transverse walls running from the foot of the dunes to low-water mark; but the great expense of such constructions has prevented their adoption on a large scale.† The principal means relied on for the protection of the sand-hills are the planting of their surfaces and the exclusion of burrowing and grazing animals. There are grasses, creeping plants, and shrubs of spontaneous growth, which flourish in loose sand, and, if protected, spread over considerable tracts, and finally convert their face into a soil capable of cultivation, or, at least, of producing forest trees. Krause enumerates one hundred and seventy-one plants as native to the coast sands of Prussia, and the observations of Andresen in Jutland carry the number of these vegetables up to two hundred and thirty-four.

---

* STARING, *De Bodem van Nederland*, i., pp. 329–331. Id., *Voormaals en Thans*, p. 163. ANDRESEN, *Om Klitformationen*, pp. 280, 295.

The creation of new dunes, by the processes mentioned in the text, seems to be much older in Europe than the adoption of measures for securing them by planting. Dr. Dwight mentions a case in Massachusetts, where a beach was restored, and new dunes formed, by planting beach grass. "Within the memory of my informant, the sea broke over the beach which connects Truro with Province Town, and swept the body of it away for some distance. The beach grass was immediately planted on the spot; in consequence of which the beach was again raised to a sufficient height, and in various places into hills."—*Travels*, iii., p. 93.

† STARING, i., pp. 310, 332.

Some of these plants, especially the *Arundo arenaria* or *arenosa*, or *Psamma* or *Psammophila arenaria*—Klittetag, or Hjelme in Danish, helm in Dutch, Dünenhalm, Sandschilf, or Hügelrohr in German, gourbet in French, and marram in English—are exclusively confined to sandy soils, and thrive well only in a saline atmosphere.* The arundo grows to the height of about twenty-four inches, but sends its strong roots with their many rootlets to a distance of forty or fifty feet. It has the peculiar property of flourishing best in the loosest soil, and a sand-shower seems to refresh it as the rain revives the thirsty plants of the common earth. Its roots bind together the dunes, and its leaves protect their surface. When the sand ceases to drift, the arundo dies, its decaying roots fertilizing the sand, and the decomposition of its leaves forming a layer of vegetable earth over it. Then follows a succession of other plants which gradually fit the sand-hills by growth and decay, for forest planting, for pasturage, and sometimes for ordinary agricultural use.

But the protection and gradual transformation of the dunes is not the only service rendered by this valuable plant. Its leaves are nutritious food for sheep and cattle, its seeds for poultry; † cordage and netting twine are manufactured from its fibres, it makes a good material for thatching, and its dried roots furnish excellent fuel. These useful qualities, unfortunately, are too often prejudicial to its growth. The peasants feed it down with their cattle, cut it for rope-making, or dig it up for fuel, and it has been found necessary to resort to severe legislation to prevent them from bringing ruin upon themselves by thus improvidently sacrificing their most effectual safeguard against the drifting of the sands.*

---

* There is some confusion in the popular use of these names, and in the scientific designations of sand-plants, and they are possibly applied to different plants in different places. Some writers style the gourbet *Calamagrostis arenaria*, and distinguish it from the Danish Klittetag or Hjelme.

† Bread, not indeed very palatable, has been made of the seeds of the arundo, but the quantity which can be gathered is not sufficient to form an important economical resource.—ANDRESEN, *Om Klitformationen*, p. 160.

In 1539 a decree of Christian III., king of Denmark, imposed a fine upon persons convicted of destroying certain species of sand-plants upon the west coast of Jutland. This ordinance was renewed and made more comprehensive in 1558, and in 1569 the inhabitants of several districts were required, by royal rescript, to do their best to check the sand-drifts, though the specific measures to be adopted for that purpose are not indicated. Various laws against stripping the dunes of their vegetation were enacted in the following century, but no active measures were taken for the subjugation of the sand-drifts until 1779, when a preliminary system of operation for that purpose was adopted. This consisted in little more than the planting of the *Arundo arenaria* and other sand-plants, and the exclusion of animals destructive to these vegetables.† Ten years later, plantations of forest trees, which have since proved so valuable a means of fixing the dunes and rendering them productive, were commenced, and have been continued ever since.‡ During this latter period, Brémontier, without any knowledge of what was doing in Denmark, experimented upon the cultivation of forest trees on the dunes of Gascony, and perfected a system, which, with some improvements in matters of detail, is still largely pursued on those shores.

---

* BERGSÖE, *Reventlovs Virksomhed*, ii., p. 4.

† Measures were taken for the protection of the dunes of Cape Cod, in Massachusetts, during the colonial period, though I believe they are now substantially abandoned. A hundred years ago, before the valley of the Mississippi, or even the rich plains of Central and Western New York, were opened to the white settler, the value of land was relatively much greater in New England than it is at present, and consequently some rural improvements were then worth making, which would not now yield sufficient returns to tempt the investment of capital. The money and the time required to subdue and render productive twenty acres of sea-sand on Cape Cod, would buy a "section" and rear a family in Illinois. The son of the Pilgrim, therefore, abandons the sand-hills, and seeks a better fortune on the fertile prairies of the West. See DWIGHT, *Travels*, i., pp. 92, 93.

‡ ANDRESEN, *Om Klitformationen*, pp. 237, 240.

The example of Denmark was soon followed in the neighboring kingdom of Prussia, and in the Netherlands; and, as we shall see hereafter, these improvements have been everywhere crowned with most flattering success.

Under the administration of Reventlov, a little before the close of the last century, the Danish Government organized a regular system of improvement in the economy of the dunes. They were planted with the arundo and other vegetables of similar habits, protected against trespassers, and at last partly covered with forest trees. By these means much waste soil has been converted into arable ground, a large growth of valuable timber obtained, and the further spread of the drifts, which threatened to lay waste the whole peninsula of Jutland, to a considerable extent arrested.

In France, the operations for fixing and reclaiming the dunes —which began under the direction of Brémontier about the same time as in Denmark, and which are, in principle and in many of their details, similar to those employed in the latter kingdom—have been conducted on a far larger scale, and with greater success, than in any other country. This is partly owing to a climate more favorable to the growth of suitable forest trees than that of Northern Europe, and partly to the liberality of the Government, which, having more important landed interests to protect, has put larger means at the disposal of the engineers than Denmark and Prussia have found it convenient to appropriate to that purpose. The area of the dunes already secured from drifting, and planted by the processes invented by Brémontier and perfected by his successors, is about 100,000 acres.* This amount of productive soil, then, has been added to the resources of France, and a still greater quantity of valuable land has been thereby rescued from the otherwise certain destruction with which it was threatened by the advance of the rolling sand-hills.

The improvements of the dunes on the coast of West Prussia began in 1795, under Sören Björn, a native of Denmark, and, with the exception of the ten years between 1807 and 1817, they have been prosecuted ever since. The methods do not differ essentially from those employed in Denmark and France, though they are modified by local circumstances, and, with respect to the trees selected for planting, by climate. In 1850, between the mouth of the Vistula and Kahlberg, 6,300 acres, including about 1,900 acres planted with pines and birches, had been secured from drifting; between Kahlberg and the eastern boundary of West Prussia, 8,000 acres; and important preliminary operations had been carried on for subduing the dunes on the west coast.*

---

* "These plantations, perseveringly continued from the time of Brémontier, now cover more than 40,000 hectares, and compose forests which are not

The tree which has been found to thrive best upon the sand-hills of the French coast, and at the same time to confine the sand most firmly and yield the largest pecuniary returns, is the maritime pine, *Pinus maritima*, a species valuable both for its timber and for its resinous products. It is always grown from seed, and the young shoots require to be protected for several seasons, by the branches of other trees, planted in rows, or spread over the surface and staked down, by the growth of the *Arundo arenaria* and other small sand-plants, or by wattled hedges. The beach, from which the sand is derived, has been generally planted with the arundo, because the pine does not thrive well so near the sea; but it is thought that a species of tamarisk is likely to succeed in that latitude even better than the arundo. The shade and the protection offered by the branching top of this pine are favorable to the growth of deciduous trees, and, while still young, of shrubs and smaller plants, which contribute more rapidly to the formation of vegetable mould, and thus, when the pine has once taken root, the redemption of the waste is considered as effectually secured.

In France, the maritime pine is planted on the sands of the

---

only the salvation of the department, but constitute its wealth."—CLAVÉ, *Études Forestières*, p. 254.

Other authors have stated the plantations of the French dunes to be much more extensive.

* KRUSE, *Dünenbau*, pp. 34, 38, 40.

interior as well as on the dunes of the seacoast, and with equal advantage. This tree resembles the pitch pine of the Southern American States in its habits, and is applied to the same uses. The extraction of turpentine from it begins at the age of about twenty years, or when it has attained a diameter of from nine to twelve inches. Incisions are made up and down the trunk, to the depth of about half an inch in the wood, and it is insisted that if not more than two such slits are cut, the tree is not sensibly injured by the process. The growth, indeed, is somewhat checked, but the wood becomes superior to that of trees from which the turpentine is not extracted. Thus treated, the pine continues to flourish to the age of one hundred or one hundred and twenty years, and up to this age the trees on an acre yield annually 300 pounds of essence of turpentine, and 250 pounds of resin, worth together not far from ten dollars. The expense of extraction and distillation is calculated at about four dollars, and a clear profit of more than five dollars per acre is left.* This is exclusive of the value of the timber, when finally cut, which, of course, amounts to a very considerable sum.

In Denmark, where the climate is much colder, hardier conifers, as well as the birch and other northern trees, are found to answer a better purpose than the maritime pine, and it is doubtful whether this tree would be able to resist the winter on the dunes of Massachusetts. Probably the pitch-pine of the Northern States, in conjunction with some of the American oaks, birches, and poplars, and especially the robinia or locust, would prove very suitable to be employed on the sand-hills of Cape Cod and Long Island. The ailanthus, now coming into notice as a sand-loving tree, some species of tamarisk, and perhaps the *Aspressus macrocarpa*, already found useful on the dunes in California, may prove valuable auxiliaries in resisting the encroachment of drifting sands, whether in America or in Europe, and the intermixing of different species would doubtless be attended with as valuable results in this as in other branches of forest economy.

---

* These processes are substantially similar to those employed in the pineries of the Carolinas, but they are better systematized and more economically conducted in France. In the latter country, all the products of the pine, even to the cones, find a remunerating market, while, in America, the price of resin is so low, that in the fierce steamboat races on the great rivers, large quantities of it are thrown into the furnaces to increase the intensity of the fires. In a carefully prepared article on the Southern pineries published in an American magazine—I think Harper's—a few years ago, it was stated that the resin from the turpentine distilleries was sometimes allowed to run to waste; and the writer, in one instance, observed a mass, thus rejected as rubbish, which was estimated to amount to two thousand barrels. Olmsted saw, near a distillery which had been in operation but a single year, a pool of resin estimated to contain three thousand barrels, which had been allowed to run off as waste. —*A Journey in the seaboard Slave States*, 1863, p. 345.

It cannot, indeed, be affirmed that human power is able to arrest altogether the incursions of the waves on sandy coasts, by planting the beach, and clothing the dunes with wood. On the contrary, both in Holland and on the French coast, it has been found necessary to protect the dunes themselves by piling and by piers and sea-walls of heavy masonry. But experience has amply shown that the processes referred to are entirely successful in preventing the movement of the dunes, and the drifting of their sands over cultivated lands behind them; and that, at the same time, the plantations very much retard the landward progress of the waters.*

Besides the special office of dune plantations already noticed, these forests have the same general uses as other woods, and they have sometimes formed by their droppings so thick a layer of vegetable mould that the sand beneath has become sufficiently secured to allow the wood to be felled, and the surface to be ploughed and cultivated with ordinary field crops.

In some cases it has been found possible to confine and cultivate coast sand-hills, even without preliminary forest plantation. Thus, in the vicinity of Cap Breton in France, a peculiar process is successfully employed, both for preventing the drifting of dunes, and for rendering the sands themselves immediately productive; but this method is applicable only in exceptional cases of favorable climate and exposure. It consists in planting vineyards upon the dunes, and protecting them by hedges of broom, *Erica scoparia*, so disposed as to form rectangles about thirty feet by forty. The vines planted in these enclosures thrive admirably, and the grapes produced by them are among the best grown in France. The dunes are so far from being an unfavorable soil for the vine, that fresh sea-sand is regularly employed as a fertilizer for it, alternating every other season with ordinary manure. The quantity of sand thus applied every second year, raises the surface of the vineyard about four or five inches. The vines are cut down every year to three or four shoots, and the raising of the soil rapidly covers the old stocks. As fast as buried, they send out new roots near the surface, and thus the vineyard is constantly renewed, and has always a youthful appearance, though it may have been already planted a couple of generations. This practice is ascertained to have been followed for two centuries, and is among the oldest well-authenticated attempts of man to resist and vanquish the dunes.*

---

* See a very interesting article entitled "Le Littoral de la France," by ELISÉE RECLUS, in the *Revue des Deux Mondes* for December, 1862, pp. [illegible] 936.

The artificial removal of dunes, no longer necessary as a protection, does not appear to have been practised upon a large scale except in the Netherlands, where the numerous canals furnish an easy and economical means of transporting the sand, and where the construction and maintenance of sea and river dikes, and of causeways and other embankments and fillings, create a great demand for that material. Sand is also employed in Holland, in large quantities, for improving the consistence of the tough clay bordering upon or underlying diluvial deposits, and for forming an artificial soil for the growth of certain garden and ornamental vegetables. When the dunes are removed, the ground they covered is restored to the domain of industry; and the quantity of land recovered in the Netherlands by the removal of the barren sands which encumbered it, amounts to hundreds and perhaps thousands of acres.

---

* BOITEL, *Mise en valeur des Terres pauvres*, pp. 212, 218.

Inland Dunes.

Vast deposits of sand, both in the form of dunes and of plains, are found far in the interior of continents, in the Old World and in the New. The deserts of Gobi, of Arabia, and of Africa have been rendered familiar by the narratives of travellers, but the sandy wildernesses of America, and even of Europe, have not yet been generally recognized as important elements in the geography of the regions where they occur. There are immense wastes of drifting sands in Poland and other interior parts of Europe, in Peru, and in the less known regions of our own Western territory, where their extent is greater than that of all the coast dunes together which have hitherto been described by European and American geographers.[*]

The inland sand-hills of both hemispheres are composed of substantially the same material and aggregated by the action of the same natural forces as the dunes of the coast. There is, therefore, a general resemblance between them, but they appear, nevertheless, to be distinguished by certain differences which a more attentive study may perhaps enable geologists to recognize in the sandstone formed by them. The sand of which they are composed comes in both principally from the bed of the sea being brought to the surface in one case by the action of the wind and the waves, in the other by geological upheaval.[†] The sand of the coast dunes is rendered, to a

---

[*] On the Niobrara river alone, the dunes cover a surface of twenty thousand square miles.—HAYDEN, *Report on Geological Survey of Wyoming*, 1870, p. 108.

[†] American observers do not agree in their descriptions of the form and character of the sand-grains which compose the interior dunes of the North American desert. C. C. Parry, geologist to the Mexican Boundary Commission, in describing the dunes near the station at a spring thirty-two miles west from the Rio Grande at El Paso, says: "The separate grains of the sand composing the sand-hills are seen under a lens to be angular, and not rounded, as would be the case in regular beach deposits."—*U. S. Mexican Boundary Survey, Report of*, vol. i., *Geological Report of C. C. Parry*, p. 10.

In the general description of the country traversed, same volume, p. 47, certain extent, cohesive by moisture and by the saline and other binding ingredients of sea-water, while long exposure to meteoric influences has in a great measure deprived the inland sands of these constituents, though there are not wanting examples of large accumulations of sand far from the sea, and yet agglutinated by saline material. Hence, as might be expected, inland dunes, when not confined by a fixed nucleus, are generally more movable than those of the coast, and the form of such dunes is more or less modified by their want of consistence. Thus, the crescent or falciform shape is described by all observers as more constant and conspicuous in these sand-hills than in those of littoral origin; they tend less to unite in continuous ridges, and they rarely attain the height or other dimensions of the dunes of the seashore.

Meyer describes the sand-hills of the Peruvian desert as perfectly falciform in shape and from seven to fifteen feet high, the chord of their arc measuring from twenty to seventy paces. The slope of the convex face is described as very small, that of the concave as high as 70° or 80°, and their surfaces were rippled. No smaller dunes were observed, nor any in the process of formation. The concave side uniformly faced the

---

Colonel Emory says that on an "examination of the sand with a microscope of sufficient power," the grains are seen to be angular, not rounded by rolling in water.

On the other hand, Blake, in *Geological Report*, *Pacific Railroad Rep.*, vol. v., p. 119, observes that the grains of the dune sand, consisting of quartz, chalcedony, carnelian, agate, rose quartz, and probably chrysolite, were much rounded; and on page 241, he says that many of the sand grains of the Colorado desert are perfect spheres.

On page 20 of a report in vol. ii. of the *Pacific Railroad Report*, by the same observer, it is said that an examination of dune sands brought from the Llano Estacado by Captain Pope, showed the grains to be "much rounded by attrition."

The sands described by Mr. Parry and Colonel Emory are not from the same localities as those examined by Mr. Blake, and the difference in their character may be due to a difference of origin or of age.

In New Mexico, sixty miles south of Fort Stanton, there are inland dunes composed of finely granulated gypsum.—*American Naturalist*, Jan. 1871, p. 695.

north-west, except towards the centre of the desert, where, for a distance of one or two hundred paces, they gradually opened to the west, and then again gradually resumed the former position.

Tschudi observed, in the same desert, two species of dunes, fixed and movable, and he ascribes a falciform shape to the movable, a conical to the fixed dunes, or *medanos*. "The medanos," he observes, "are hillock-like elevations of sand, some having a firm, others a loose base. The former [latter], which are always crescent-shaped, are from ten to twenty feet high, and have an acute crest. The inner side is perpendicular, and the outer or bow side forms an angle with a steep inclination downwards.[*] When driven by violent winds, the medanos pass rapidly over the plains. The smaller and lighter ones move quickly forward, before the larger; but the latter soon overtake and crush them, whilst they are themselves shivered by the collision. These medanos assume all sorts of extraordinary figures, and sometimes move along the plain in rows forming most intricate labyrinths. . . . A plain often appears to be covered with a row of medanos, and some days afterwards it is again restored to its level and uniform aspect. . . .

"The medanos with immovable bases are formed on the blocks of rocks which are scattered about the plain. The sand is driven against them by the wind, and as soon as it reaches the top point, it descends on the other side until that is likewise covered; thus gradually arises a conical-formed hill.[†] Entire hillock chains with acute crests are formed in a similar manner. . . . On their southern declivities are found vast masses of sand, drifted thither by the mid-day gales. The northern declivity, though not steeper than the southern, is only sparingly covered with sand. If a hillock chain somewhat distant from the sea extends in a line parallel with the Andes, namely, from S. S. E. to N. N. W., the western declivity is almost entirely free of sand, as it is driven to the plain below by the south-east wind, which constantly alternates with the wind from the south." *

---

[*] The dunes of the plains between Bokhara and the Oxus are all horse-shoe shaped, convex towards the north, from which the prevailing wind blows. On this side they are sloping, inside precipitous, and from fifteen to twenty feet high.—BURNES, *Journal in Bokhara*, ii., pp. 1, 2.

[†] The sand-hills observed by Desor in the Algerian desert were fixed, changing their form only on the surface as sand was blown to and from them.—*Sahara und Atlas*, 1865, p. 21.

It is difficult to reconcile this description with that of Meyen, but if confidence is to be reposed in the accuracy of either observer, the formation of the sand-hills in question must be governed by very different laws from those which determine the structure of coast dunes. Captain Gilliss, of the American navy, found the sand-hills of the Peruvian desert to be in general crescent-shaped, as described by Meyen, and a similar structure is said to characterize the inland dunes of the Llano Estacado and other plateaus of the North American desert, though these latter are of greater height and other dimensions than those described by Meyen. There is no very obvious explanation of this difference in form between maritime and inland sand-hills, and the subject merits investigation. It is, however, probable that the great mobility of the flying dunes of the Peruvian desert is an effect of their dryness, no rain falling in that desert, and of the want of salt or other binding material to hold their particles together.

Inland Sand Plains.

The inland sand plains of Europe are either derived from the drifting of dunes or other beach sands, or consist of diluvial deposits, or are ancient sea-beds uplifted by geological upheaval. As we have seen, when once the interior of a dune is laid open to the wind, its contents are soon scattered far and wide over the adjacent country, and the beach sands, no longer checked by the rampart which nature had constrained them to build against their own encroachments, are also carried to considerable distances from the coast. Few regions have suffered so much from this cause, in proportion to their extent, as the peninsula of Jutland. So long as the woods, with which nature had planted the Danish dunes, were spared, they seem to have been stationary, and we have no historical evidence, of an earlier date than the sixteenth century, that they had become in any way injurious. From that period there are frequent notices of the invasions of cultivated grounds by the sands; and excavations are constantly bringing to light proof of human habitation and of agricultural industry, in former ages, on soils now buried beneath deep drifts from the dunes and beaches of the seacoast.*

---

* *Travels in Peru*, New York, 1848, chap. ix.

Extensive tracts of valuable plain land in the Netherlands and in France have been covered in the same way with a layer of sand deep enough to render them infertile, and they can be restored to cultivation only by processes analogous to those employed for fixing and improving the dunes.† Diluvial sand plains, also, have been reclaimed by these methods in the Duchy of Austria, between Vienna and the Semmering ridge, in Jutland, and in the great champaign country of Northern Germany, especially the Mark Brandenburg, where artificial forests can be propagated with great ease, and where, consequently, this branch of industry has been pursued on a great scale, and with highly beneficial results, both as respects the supply of forest products and the preparation of the soil for agricultural use.

As has been already observed, inland sands are generally looser, dryer, and more inclined to drift, than those of the seacoast, where the moist and saline atmosphere of the ocean keeps them always more or less humid and cohesive. The sands of the valley of the Lower Euphrates—themselves probably of submarine origin, and not derived from dunes—

---

* For details, consult ANDRESEN, *Om Klitformationen*, pp. 223, 236.

† When the deposit is not very deep, and the adjacent land lying to the leeward of the prevailing winds is covered with water, or otherwise worthless, the surface is sometimes freed from the drifts by repeated harrowings, which loosen the sand, so that the wind takes it up and transports it to grounds where accumulations of it are less injurious.

are advancing to the north-west with a rapidity which seems fabulous when compared with the slow movement of the sand-hills of Gascony and the Low German coasts. Loftus, speaking of Niliyya, an old Arab town a few miles east of the ruins of Babylon, says that, "in 1848, the sand began to accumulate around it, and in six years, the desert, within a radius of six miles, was covered with little, undulating domes, while the ruins of the city were so buried that it is now impossible to trace their original form or extent." * Loftus considers this sand-flood as the "vanguard of those vast drifts which advancing from the south-east, threaten eventually to overwhelm Babylon and Baghdad."

An observation of Layard, cited by Loftus, appears to me to furnish a possible explanation of this irruption. He "passed two or three places where the sand, issuing from the earth like water, is called 'Aioun-er-rummal,' sand springs." These "springs" are very probably merely the drifting of sand from the ancient subsoil, where the protecting crust of aquatic deposit and vegetable earth has been broken through, as in the case of the drift which arose from the upturning of an oak mentioned on a former page. When the valley of the Euphrates was regularly irrigated and cultivated, the underlying sands were bound by moisture, alluvial slime, and vegetation; but now, that all improvement is neglected, and the surface, no longer watered, has become parched, powdery, and naked, a

---

* *Travels and Researches in Chaldæa*, chap. ix.

Dwight mentions (*Travels*, vol. iii., p. 101) an instance of great mischief from the depasturing of the beach grass which had been planted on a sand plain in Cape Cod: "Here, about one thousand acres were entirely blown away to the depth, in many places, of ten feet. . . . Not a green thing was visible except the whortleberries, which tufted a few lonely hillocks rising to the height of the original surface and prevented by this defence from being blown away also. These, although they varied the prospect, added to the gloom by their strongly picturesque appearance, by marking exactly the original level of the plain, and by showing us in this manner the immensity of the mass which had been thus carried away by the wind. The beach grass had been planted here, and the ground had been formerly enclosed; but the gates had been left open, and the cattle had destroyed this invaluable plant."

mere accidental fissure in the superficial stratum may soon be enlarged to a wide opening, that will let loose sand enough to overwhelm a province.

The Landes of Gascony.

The most remarkable sand plain of France lies at the southwestern extremity of the empire, and is generally known as the Landes, or heaths, of Gascony. Clavé thus describes it: "Composed of pure sand, resting on an impermeable stratum called *alios*, the soil of the Landes was, for centuries, considered incapable of cultivation.[*] Parched in summer, drowned in winter, it produced only ferns, rushes, and heath, and scarcely furnished pasturage for a few half-starved flocks. To crown its miseries, this plain was continually threatened by the encroachments of the dunes. Vast ridges of sand, thrown up by the waves, for a distance of more than fifty leagues along the coast, and continually renewed, were driven inland by the west wind, and, as they rolled over the plain, they buried the soil and the hamlets, overcame all resistance, and advanced with fearful regularity. The whole province seemed devoted to certain destruction, when Brémontier invented his method of fixing the dunes by plantations of the maritime pine."[†]

Although the Landes had been almost abandoned for ages, they show numerous traces of ancient cultivation and prosperity, and it is principally by means of the encroachments of the sands that they have become reduced to their present desolate condition. The destruction of the coast towns and harbors, which furnished markets for the products of the plains, the damming up of the rivers, and the obstruction of the smaller channels of natural drainage by the advance of the dunes, were no doubt very influential causes; and if we add the drifting of the sea-sand over the soil, we have at least a partial explanation of the decayed agriculture and diminished population of this great waste. When the dunes were once arrested, and the soil to the east of them was felt to be secure against invasion by them, experiments, in the way of agricultural improvement, by drainage and plantation, were commenced, and they have been attended with such signal success, that the complete recovery of one of the dreariest and most extensive wastes in Europe may be considered as both a probable and a near event.*

---

[*] The *alios*, which from its color and consistence was supposed to be a ferruginous formation, appears from recent observations to contain little iron and to owe most of its peculiar properties to vegetable elements carried down into the soil by the percolation of rain-water. See *Revue des Eaux et Forêts* for 1870, p. 301.

[†] *Études Forestières*, p. 250. See, also, RECLUS, *La Terre*, i., 105, 106.

In the northern part of Belgium, and extending across the confines of Holland, is another very similar heath plain, called the Campine. This is a vast sand flat, interspersed with marshes and inland dunes, and, until recently, considered almost wholly incapable of cultivation. Enormous sums had been expended in reclaiming it by draining and other familiar agricultural processes, but without results at all proportional to the capital invested. In 1849, the unimproved portion of the Campine was estimated at little less than three hundred and fifty thousand acres. The example of France prompted experiments in the planting of trees, especially the maritime pine, upon this barren waste, and the results have now been such as to show that its sands may both be fixed and made productive, not only without loss, but with positive pecuniary advantage.[*]

---

* LAVERGNE, *Economie Rurale de la France*, p. 300, estimates the area of the Landes of Gascony at 700,000 hectares, or about 1,700,000 acres. The same author states (p. 304), that when the Moors were driven from Spain by the blind cupidity and brutal intolerance of the age, they demanded permission to establish themselves in this desert; but political and religious prejudices prevented the granting of this liberty. At this period the Moors were a far more cultivated people than their Christian persecutors, and they had carried many arts, that of agriculture especially, to a higher pitch than any other European nation. But France was not wise enough to accept what Spain had cast out, and the Landes remained a waste for three centuries longer.

For a brilliant account of the improvement of the Landes, see Edmond About, *Le Progrès*, chap. vii.

The forest of Fontainebleau, which contains above 40,000 acres, is not a plain, but its soil is composed almost wholly of sand, interspersed with ledges of rock. The sand forms not less than ninety-eight per cent. of the earth, and, as it is almost without water, it would be a drifting desert but for the artificial propagation of forest trees upon it.

The Landes of Sologne and of Brenne are less known than those of Gascony, because they are not upon the old great lines of communication. They once composed a forest of 1,200,000 acres, but by clearing the woods have relapsed into their primitive condition of a barren sand waste. Active efforts are now in progress to reclaim them.

There are still unsubdued sand wastes in many parts of interior Europe not familiarly known to tourists or even geographers. "Olkuez and Schiewier in Poland," says Naumann, "lie in true sand deserts, and a boundless plain of sand stretches around Ozenstockau, on which there grows neither tree nor shrub. In heavy winds, this plain resembles a rolling sea, and the sand-hills rise and disappear like the waves of the ocean. The heaps of waste from the Olkuez mines are covered with sand to the depth of four fathoms."[†] No attempts have yet been made to subdue the sands of Poland, but when peace and prosperity shall be restored to that unhappy country, there is no reasonable doubt that the measures, which have proved so successful on similar formations in Germany and near Odessa, may be employed with advantage in the Polish deserts.[‡]

---

[*] *Economie Rurale de la Belgique, par* EMILE DE LAVELEYE, *Revue des Deux Mondes*, Juin, 1861, pp. 617–644. The quantity of land annually reclaimed on the Campine is stated at about 4,000 acres. Canals for navigation and irrigation have been constructed through the Campine, and it is said that its barren sands, improved at an expense of one hundred dollars per acre, yield, from the second year, a return of twenty-five dollars to the acre.

[†] *Geognosie*, ii., p. 1173.

[‡] "Sixteen years ago," says an Odessa landholder, "I attempted to fix the sand of the steppes, which covers the rocky ground to the depth of a foot, and forms moving hillocks with every change of wind. I tried acacias and pines in vain; nothing would grow in such a soil. At length I planted the varnish tree, or *ailanthus*, which succeeded completely in binding the sand." This result encouraged the proprietor to extend his plantations over both dunes and sand steppes, and in the course of sixteen years this rapidly growing tree had formed real forests. Other landholders have imitated his example with great advantage.—RENTSCH, *Der Wald*, pp. 44, 45.

CHAPTER VI.

GREAT PROJECTS OF PHYSICAL CHANGE ACCOMPLISHED OR PROPOSED BY MAN.

Cutting of Isthmuses—Canal of Suez—Maritime Canals in Greece—Canals to Dead Sea—Canals to Libyan Desert—Maritime Canals in Europe—Cape Cod Canal—Changes in Caspian—Diversion of the Nile—Diversion of the Rhine—Improvements in North American Hydrography—Soil below Rock—Covering Rock with Earth—Desert Valleys—Effects of Mining—Duponchel's Plans of Improvement—Action of Man on the Weather—Resistance to Great Natural Forces—Incidental Effects of Human Action—Nothing small in Nature.

IN a former chapter I spoke of the influence of human action on the surface of the globe as immensely superior in degree to that exerted by brute animals, if not essentially different from it in kind. The eminent Italian geologist, Stoppani, goes further than I had ventured to do, and treats the action of man as a new physical element altogether *sui generis*. According to him, the existence of man constitutes a geological period which he designates as the *anthropozoic era*. "The creation of man," says he, "was the introduction of a new element into nature, of a force wholly unknown to earlier periods." "It is a new telluric force which in power and universality may be compared to the greater forces of the earth." * It has already been abundantly shown that, though the undesigned and unforeseen results of man's action on the geographical conditions of the earth have perhaps been hitherto greater and more revolutionary than the effects specially aimed at by him, yet there is scarcely any assignable limit to his present and prospective voluntary controlling power over terrestrial nature.

---

* *Corso di Geologia*, Milano, 1873, vol. ii., cap. xxxi., § 1327.

Cutting of Marine Isthmuses.

Besides the great enterprises of physical transformation of which I have already spoken, other works of internal improvement or change have been projected in ancient and modern times, the execution of which would produce considerable, and, in some cases, extremely important, revolutions in the face of the earth. Some of the schemes to which I refer are evidently chimerical; others are difficult, indeed, but cannot be said to be impracticable, though discouraged by the apprehension of disastrous consequences from the disturbance of existing natural or artificial arrangements; and there are still others, the accomplishment of which is ultimately certain, though for the present forbidden by economical considerations.

Nature sometimes mocks the cunning and the power of man by spontaneously performing, for his benefit, works which he shrinks from undertaking, and the execution of which by him she would resist with unconquerable obstinacy. A dangerous sand bank, that all the enginery of the world could not dredge out in a generation, may be carried off in a night by a strong river-flood, or by a current impelled by a violent wind from an unusual quarter, and a passage scarcely navigable by fishing-boats may be thus converted into a commodious channel for the largest ship that floats upon the ocean. In the remarkable gulf of Liimfjord in Jutland, referred to in the preceding chapter, nature has given a singular example of a canal which she alternately opens as a marine strait, and, by shutting again, converts into a fresh-water lagoon. The Liimfjord was doubtless originally an open channel from the Atlantic to the Baltic between two islands, but the sand washed up by the sea blocked up the western entrance, and built a wall of dunes to close it more firmly. This natural dike, as we have seen, has been more than once broken through, and it is perhaps in the power of man, either permanently to maintain the barrier, or to remove it and keep a navigable channel constantly open. If the Liimfjord becomes an open strait, the washing of sea-sand through it would perhaps block some of the belts and small channels now important for the navigation of the Baltic, and the direct introduction of a tidal current might produce very perceptible effects on the hydrography of the Cattegat.

When we consider the number of narrow necks or isthmuses which separate gulfs and bays of the sea from each other, or from the main ocean, and take into account the time and cost, and risks of navigation which would be saved by executing channels to connect such waters, and thus avoiding the necessity of doubling long capes and promontories, or even continents, it seems strange that more of the enterprise and money which have been so lavishly expended in forming artificial rivers for internal navigation should not have been bestowed upon the construction of maritime canals. Many such have been projected in early and in recent ages, and some trifling cuts between marine waters had been actually made; but before the construction of the Suez Canal, no work of this sort, possessing real geographical or even commercial importance, had been effected.

These enterprises are attended with difficulties and open to objections which are not, at first sight, obvious. Nature guards well the chains by which she connects promontories with mainlands, and binds continents together. Isthmuses are usually composed of adamantine rock or of shifting sands—the latter being much the more refractory material to deal with. In all such works there is a necessity for deep excavation below low-water mark—always a matter of great difficulty; the dimensions of channels for sea-going ships must be much greater than those of canals of inland navigation; the height of the masts or smokepipes of that class of vessels would often render bridging impossible, and thus a ship-canal might obstruct a communication more important than that which it was intended to promote; the securing of the entrances of marine canals and the construction of ports at their termini would in general be difficult and expensive, and the harbors and the channel which connected them would be extremely liable to fill up by deposits washed in from sea and shore. Besides all this there is, in many cases, an alarming uncertainty as to the effects of joining together waters which nature has put asunder. A new channel may deflect strong currents from safe courses, and thus occasion destructive erosion of shores otherwise secure, or promote the transportation of sand or slime to block up important harbors, or it may furnish a powerful enemy with dangerous facilities for hostile operations along the coast.

The most colossal project of canalization ever suggested, whether we consider the physical difficulties of its execution, the magnitude and importance of the waters proposed to be united, or the distance which would be saved in navigation, is that of a channel between the Gulf of Mexico and the Pacific, across the Isthmus of Darien. I do not now speak of a lock-canal, by way of the Lake of Nicaragua or any other route—for such a work would not differ essentially from other canals, and would scarcely possess a geographical character—but of an open cut between the two seas. The late survey by Captain Selfridge, showing that the lowest point on the dividing ridge is 763 feet above the sea-level, must be considered as determining in the negative the question of the possibility of such a cut, by any means now at the control of man; and both the sanguine expectations of benefits, and the dreary suggestions of danger, from the realization of this great dream, may now be dismissed as equally chimerical.

Suez Canal.

The cutting of the Isthmus of Suez—the grandest and most truly cosmopolite physical improvement ever undertaken by man—threatens none of these dangers, and its only immediate geographical effect will probably be that interchange between the aquatic animal and vegetable life of two seas and two zones to which I alluded in a former chapter.*

A collateral feature of this great enterprise deserves notice as possessing no inconsiderable geographical importance. I refer to the conduit or conduits constructed from the Nile to the isthmus, primarily to supply fresh water to the laborers on the great canal, and ultimately to serve as aqueducts for the city of Suez and other towns on the line of the canal, and for the irrigation and reclamation of a large extent of desert soil. In the flourishing days of the Egyptian empire, the waters of the Nile were carried over important districts east of the river. In later ages, most of this territory relapsed into a desert, from the decay of the canals which once fertilized it. There is no difficulty in restoring the ancient channels, or in constructing new, and thus watering not only all the soil that the wisdom of the Pharaohs had improved, but much additional land. Hundreds of square miles of arid sand waste would thus be converted into fields of perennial verdure, and the geography of Lower Egypt would be thereby sensibly changed. Considerable towns are growing up at both ends of the channel, and at intermediate points, all depending on the maintenance of aqueducts from the Nile, both for water and for the irrigation of the neighboring fields which are to supply them with bread. Important interests will thus be created, which will secure the permanence of the hydraulic works and of the geographical changes produced by them, and Suez, or Port Said, or Ismailieh, may become the capital of the government which has been so long established at Cairo.

Maritime Canals in Greece.

A maritime canal executed and another projected in ancient times, the latter of which is again beginning to excite attention, deserve some notice, though their importance is of a commercial rather than a geographical character. The first of these is the cut made by Xerxes through the rock which connects the promontory of Mount Athos with the mainland; the other, a navigable canal through the Isthmus of Corinth. In spite of the testimony of Herodotus and Thucydides, the Romans classed the canal of Xerxes among the fables of "mendacious Greece," and yet traces of it are perfectly distinct at the present day through its whole extent, except at a single point where, after it had become so choked as to be no longer navigable, it was probably filled up to facilitate communication by land between the promontory and the country in the rear of it.

---

* According to an article by Ascherson, in Petermann's *Mittheilungen*, vol. xvii., p. 247, the sea-grass floras of the opposite sides of the Isthmus of Suez are as different as possible. It does not appear whether they have yet intermixed.

The emperor Nero commenced the construction of a canal across the Isthmus of Corinth, solely to facilitate the importation of grain from the East for distribution among the citizens of Rome—for the encouragement of general commerce was no part of the policy either of the republic or the empire, and though the avidity of traders, chiefly foreigners, secured to the luxury of the imperial city an abundant supply of far-fetched wares, yet Rome had nothing to export in return. The line of Nero's excavations is still traceable for three-quarters of a mile, or more than a fifth of the total distance between gulf and gulf.

If the fancy kingdom of Greece shall ever become a sober reality, escape from its tutelage and acquire such a moral as well as political status that its own capitalists—who now prefer to establish themselves and employ their funds anywhere else rather than in their native land—have any confidence in the permanency of its institutions, a navigable channel may be opened between the gulfs of Lepanto and Ægina. The annexation of the Ionian Islands to Greece will make such a work almost a political necessity, and it would not only furnish valuable facilities for domestic intercourse, but become an important channel of communication between the Levant and the countries bordering on the Adriatic, or conducting their trade through that sea.

Short as is the distance, the work would be a somewhat formidable undertaking, for the lowest point of the summit ridge of the isthmus is stated to be 246 feet above the water, and consequently the depth of excavation must be not less than 275 feet.

As I have said, the importance of this latter canal and of a navigable channel between Mount Athos and the continent would be chiefly commercial, but both of them would be conspicuous instances of the control of man over nature in a field where he has thus far done little to interfere with her spontaneous arrangements. If they were constructed upon such a scale as to admit of the free passage of the water through them, in either direction, as the prevailing winds should impel it, they would exercise a certain influence on the coast currents, which are important as hydrographical elements, and also as producing abrasion of the coast and a drift at the bottom of seas, and hence they would be entitled to rank higher than simply as artificial means of transit.

It has been thought practicable to cut a canal across the peninsula of Gallipoli from the outlet of the Sea of Marmora into the Gulf of Saros. It may be doubted whether the mechanical difficulties of such a work would not be found insuperable; but when Constantinople shall recover the important political and commercial rank which naturally belongs to her, the execution of such a canal will be recommended by strong reasons of military expediency, as well as by the interests of trade. An open channel across the peninsula would divert a portion of the water which now flows through the Dardanelles, diminishing the rapidity of that powerful current, and thus in part remove the difficulties which obstruct the navigation of the strait. It would considerably abridge the distance by water between Constantinople and the northern coast of the Ægean, and it would have the important advantage of obliging an enemy to maintain two blockading fleets instead of one.

Canals communicating with Dead Sea.

The project of Captain Allen for opening a new route to India by cuts between the Mediterranean and the Dead Sea, and between the Dead Sea and the Red Sea, presents many interesting considerations.* The hypsometrical observations of Bertou, Roth, and others, render it highly probable, if not certain, that the watershed in the Wadi-el-Araba between the Dead Sea and the Red Sea is not less than three hundred feet above the main level of the latter, and if this is so, the execution of a canal from the one sea to the other is quite out of the question. But the summit level between the Mediterranean and the Jordan, near Jezreel, is believed to be little, if at all, more than one hundred feet above the sea, and the distance is so short that the cutting of a channel through the dividing ridge would probably be found by no means an impracticable undertaking. Although, therefore, we have no reason to believe it possible to open a navigable channel to India by way of the Dead Sea, there is not much doubt that the basin of the latter might be made accessible from the Mediterranean.

The level of the Dead Sea lies 1,316.7 feet below that of the ocean. It is bounded east and west by mountain ridges, rising to the height of from 2,000 to 4,000 feet above the ocean. From its southern end, a depression called the Wadi-el-Araba extends to the Gulf of Akaba, the eastern arm of the Red Sea. The Jordan empties into the northern extremity of the Dead Sea, after having passed through the Lake of Tiberias at an elevation of 663.4 feet above the Dead Sea, or 653.3 below the Mediterranean, and drains a considerable valley north of the lake, as well as the plain of Jericho, which lies between the lake and the sea. If the waters of the Mediterranean were admitted freely into the basin of the Dead Sea, they would raise its surface to the general level of the ocean, and consequently flood all the dry land below that level within the basin.

---

* *The Dead Sea a new Route to India.* 2 vols. 12mo, London, 1855.

I do not know that accurate levels have been taken in the valley of the Jordan above the Lake of Tiberias, and our information is very vague as to the hypsometry of the northern part of the Wadi-el-Araba. As little do we know where a contour line, carried around the basin at the level of the Mediterranean, would strike its eastern and western borders. We cannot, therefore, accurately compute the extent of now dry land which would be covered by the admission of the waters of the Mediterranean, or the area of the inland sea which would be thus created. Its length, however, would certainly exceed one hundred and fifty miles, and its mean breadth, including its gulfs and bays, could scarcely be less than fifteen, perhaps even twenty. It would cover very little ground now occupied by civilized or even uncivilized man, though some of the soil which would be submerged—for instance, that watered by the Fountain of Elisha and other neighboring sources—is of great fertility, and, under a wiser government and better civil institutions, might rise to importance, because, from its depression, it possesses a very warm climate, and might supply South-eastern Europe with tropical products more readily than they can be obtained from any other source. Such a canal and sea would be of no present commercial importance, because they would give access to no new markets or sources of supply; but when the fertile valleys and the deserted plains east of the Jordan shall be reclaimed to agriculture and civilization, these waters would furnish a channel of communication which might become the medium of a very extensive trade.

Whatever might be the economical results of the opening and filling of the Dead Sea basin, the creation of a new evaporable area, adding not less than 2,000 or perhaps 3,000 square miles to the present fluid surface of Syria, could not fail to produce important meteorological effects. The climate of Syria would probably be tempered, its precipitation and its fertility increased, the courses of its winds and the electrical condition of its atmosphere modified. The present organic life of the valley would be extinguished, and many tribes of plants and animals would emigrate from the Mediterranean to the new home which human art had prepared for them. It is possible, too, that the addition of 1,300 feet, or forty atmospheres, of hydrostatic pressure upon the bottom of the basin might disturb the equilibrium between the internal and the external forces of the crust of the earth at this point of abnormal configuration, and thus produce geological convulsions the intensity of which cannot be even conjectured.

It is now established by the observations of Rohlf and others that Strabo was right in asserting that a considerable part of the Libyan desert, or Sahara, lay below the level of the Mediterranean. At some points the depression exceeds 325 feet, and at Siwah, in the oasis of Jupiter Ammon, it is not less than 130 feet. It has been proposed to cut a canal through the coast dunes, on the shore south of the Syrtis Major, or Dschun el Kebrit of the Arabs, and another project is to reopen the communication which appears to have once existed between the Palus Tritonis, or Sebcha el Nandid, and the Syrtis Parva. As we do not know the southern or eastern limits of this depression, we cannot determine the area which would thus be covered with water, but it would certainly be many thousands of square miles in extent, and the climatic effects would doubtless be sensible through a considerable part of Northern Africa, and possibly even in Europe. The rapid evaporation would require a constant influx of water from the Mediterranean, which might perhaps perceptibly influence the current through the Straits of Gibraltar.

Maritime Canals in Europe.

A great navigable cut across the peninsula of Jutland, forming a new and short route between the North Sea and the Baltic, if not actually commenced, is determined upon. The motives for opening such a communication are perhaps rather to be found in political than in geographical or even commercial considerations, but it will not be without an important bearing on the material interests of all the countries to whose peoples it will furnish new facilities for communication and traffic.

The North Holland canal between the Helder and the port of Amsterdam, a distance of fifty miles, executed a few years since at a cost of $5,000,000, and with dimensions admitting the passage of a frigate, was a magnificent enterprise, but it is thrown quite into the shade by the shorter channel now in process of construction for bringing that important city into almost direct communication with the North Sea, and thus restoring to it something at least of its ancient commercial importance. The work involves some of the heaviest hydraulic operations yet undertaken, including the construction of great dams, locks, dikes, embankments, and the execution of draining works and deep cuttings under circumstances of extreme difficulty. In the course of these labors many novel problems have presented themselves for practical solution by the ingenuity of modern engineers, and the new inventions and processes thus necessitated are valuable contributions to our means of physical improvement.

Cape Cod Canal.

The opening of a navigable cut through the narrow neck which separates the southern part of Cape Cod Bay in Massachusetts from the Atlantic, was long ago suggested, and there are few coast improvements on the Atlantic shores of the United States which are recommended by higher considerations of utility. It would save the most important coasting trade of the United States the long and dangerous navigation around Cape Cod, afford a new and safer entrance to Boston harbor for vessels from Southern ports, secure a choice of passages, thus permitting arrivals upon the coast and departures from it at periods when wind and weather might otherwise prevent them, and furnish a most valuable internal communication in case of coast blockade by a foreign power. The difficulties of the undertaking are no doubt formidable, but the expense of maintenance and the uncertainty of the effects of currents setting through the new strait are still more serious objections.*

Changes in the Caspian.

The Russian Government has contemplated the establishment of a nearly direct water communication between the Caspian Sea and the Sea of Azoff, partly by natural and partly by artificial channels, and there are now navigable canals between the Don and the Volga; but these works, though not wanting in commercial and political interest, do not possess any geographical importance. It is, however, very possible to produce appreciable geographical changes in the basin of the Caspian by the diversion of the great rivers which flow from Central Russia. The surface of the Caspian is eighty-three feet below the level of the Sea of Azoff, and its depression has been explained upon the hypothesis that the evaporation exceeds the supply derived, directly and indirectly, from precipitation, though able physicists now maintain that the sinking of this sea is due to a subsidence of its bottom from geological causes. At Tsaritsin, the Don, which empties into the Sea of Azoff, and the Volga, which pours into the Caspian, approach each other within ten miles. Near this point, by means of open or subterranean canals, the Don might be turned into the Volga, or the Volga into the Don. If we suppose the whole or a large proportion of the waters of the Don to be thus diverted from their natural outlet and sent down to the Caspian, the equilibrium between the evaporation from that sea and its supply of water might be restored, or its level even raised above its ancient limits. If the Volga were turned into the Sea of Azoff, the Caspian would be reduced in dimensions until the balance between loss and gain should be re-established, and it would occupy a much smaller area than at present. Such changes in the proportion of solid and fluid surface would have some climatic effects in the territory which drains into the Caspian, and on the other hand, the introduction of a greater quantity of fresh water into the Sea of Azoff would render that gulf less saline, affect the character and numbers of its fish, and perhaps be not wholly without sensible influence on the water of the Black Sea.

---

* The opening of a channel across Cape Cod would have, though perhaps to a smaller extent, the same effects in interchanging the animal life of the southern and northern shores of the isthmus, as in the case of the Suez Canal; for although the breadth of Cape Cod does not anywhere exceed twenty miles, and is in some places reduced to one, it appears from the official reports on the Natural History of Massachusetts, that the population of the opposite waters differs widely in species.

Not having the original documents at hand, I quote an extract from the *Report on the Invertebrate Animals of Mass.*, given by Thoreau, *Excursions*, p. 69: "The distribution of the marine shells is well worthy of notice as a geological fact. Cape Cod, the right arm of the Commonwealth, reaches out into the ocean some fifty or sixty miles. It is nowhere many miles wide; but this narrow point of land has hitherto proved a barrier to the migration of many species of mollusca. Several genera and numerous species, which are separated by the intervention of only a few miles of land, are effectually prevented from mingling by the Cape, and do not pass from one side to the other. . . . . Of the one hundred and ninety-seven marine species, eighty-three do not pass to the south shore, and fifty are not found on the north shore of the Cape."

Probably the distribution of the species of mollusks is affected by unknown local conditions, and therefore an open canal across the Cape might not make every species that inhabits the waters on one side common to those of the other; but there can be no doubt that there would be a considerable migration in both directions.

The fact stated in the report may suggest an important caution in drawing conclusions upon the relative age of formations from the character of their fossils. Had a geological movement or movements upheaved to different levels the bottoms of waters thus separated by a narrow isthmus, and dislocated the connection between those bottoms, naturalists, in after ages, reasoning from the character of the fossil faunas, might have assigned them to different, and perhaps very widely distant, periods.

Diversion of the Nile.

Perhaps the most remarkable project of great physical change, proposed or threatened in earlier ages, is that of the diversion of the Nile from its natural channel, and the turning of its current into either the Libyan Desert or the Red Sea. The Ethiopian or Abyssinian princes more than once menaced the Memlouk sultans with the execution of this alarming project, and the fear of so serious an evil is said to have induced the Moslems to conciliate the Abyssinian kings by large presents, and by some concessions to the oppressed Christians of Egypt. Indeed, Arabian historians affirm that in the tenth century the Ethiopians dammed the river, and, for a whole year, cut off its waters from Egypt.* The probable explanation of this story is to be found in a season of extreme drought, such as have sometimes occurred in the valley of the Nile.

The Libyan Desert, above the junction of the two principal branches of the Nile at Khartum, is so much higher than the level of the river below that point, that there is no reason to believe a new channel for the united waters of the two streams could be found in that direction; but the Bahr-el-Abiad flows through, if it does not rise in, a great table-land, and some of its tributaries are supposed to communicate in the rainy season with branches of great rivers flowing in quite another direction. Hence it is probable that a portion at least of the waters of this great arm of the Nile—and perhaps a quantity the abstraction of which would be sensibly felt in Egypt—might be sent to the Atlantic by the Congo or Niger, lost in inland lakes and marshes in Central Africa, or employed to fertilize the Libyan-sand wastes.

About the beginning of the sixteenth century, Albuquerque the "Terrible" revived the scheme of turning the Nile into the Red Sea, with the hope of destroying the transit trade through Egypt by way of Kosseir. In 1525 the King of Portugal was requested by the Emperor of Abyssinia to send him engineers for that purpose; a successor of that prince threatened to attempt the project about the year 1700, and even as late as the French occupation of Egypt, the possibility of driving out the intruder by this means was suggested in England.

---

* "Some haue writtē, that by certain kings inhabiting aboue, the *Nilus* should there be stopped; & at a time prefixt, let loose vpon a certaine tribute payd them by the *Aegyptians.* The error springing perhaps frō a truth (as all wandring reports for the most part doe) in that the *Sultan* doth pay a certaine annuall summe to the *Abissin* Emperour for not diuerting the course of the Riuer, which (they say) he may, or impouerish it at the least."—GEORGE SANDYS, *A Relation of a Journey, etc.*, p. 98. See, also, VANSLEB, *Voyage en Égypte*, p. 61.

It cannot be positively affirmed that the diversion of the waters of the Nile to the Red Sea is impossible. In the chain of mountains which separates the two valleys, Brown found a deep depression or wadi, extending from the one to the other, apparently at no great elevation above the bed of the river, but the height of the summit level was not measured.

Admitting the possibility of turning the whole river into the Red Sea, let us consider the probable effect of the change. First and most obvious is the total destruction of the fertility of Middle and Lower Egypt, the conversion of that part of the valley into a desert, and the extinction of its imperfect civilization, if not the absolute extirpation of its inhabitants. This is the calamity threatened by the Abyssinian princes and the ferocious Portuguese warrior, and feared by the Sultans of Egypt. Beyond these immediate and palpable consequences neither party then looked; but a far wider geographical area, and far more extensive and various human interests, would be affected by the measure. The spread of the Nile during the annual inundation covers, for many weeks, several thousand square miles with water, and at other seasons of the year pervades the same and even a larger area with moisture by infiltration. The abstraction of so large an evaporating surface from the southern shores of the Mediterranean could not but produce important effects on many meteorological phenomena, and the humidity, the temperature, the electrical condition and the atmospheric currents of North-eastern Africa might be modified to a degree that would sensibly affect the climate of Europe.

The Mediterranean, deprived of the contributions of the Nile, would require a larger supply, and of course a stronger curmore complete, and it is certain that there are numerous points within our territory where the courses of great rivers, or the discharge of considerable lakes, might be completely diverted, or at least partially directed into different channels.

The surface of Lake Erie is 565 feet above that of the Hudson at Albany, and it is so near the level of the great plain lying east of it, that it was found practicable to supply the western section of the canal, which unites it with the Hudson, with water from the lake, or rather from the Niagara which flows out of it. The greatest depth of water yet sounded in Lake Erie is but two hundred and seventy feet, the mean depth one hundred and twenty. Open canals parallel with the Niagara, or directly towards the Genesee, might be executed upon a scale which would exercise an important influence on the drainage of the lake, if there were any adequate motive for such an undertaking. Still easier would it be to enlarge the outlet for the waters of Lake Superior at the Saut St. Mary—where the river which drains the lake descends twenty-two feet in a single mile—and thus to produce incalculable effects, both upon that lake and upon the great chain of inland waters which communicate with it.

The summit level between the surface of Lake Michigan at its mean height and that of the River Des Plaines, a tributary of the Illinois, at a point some ten miles west of Chicago, is but ten and a half feet above the lake. The lake once discharged a part or the whole of its waters into the valley of the Des Plaines. A slight upheaval, at an unknown period, elevated the bed of the Des Plaines, and the prairie between it and the lake, to their present level, and the outflow of the lake was turned into a new direction. The bed of the Des Plaines is higher than the surface of the lake, and in recent times the Des Plaines, when at flood, has sent more or less of its waters across the ridge into the bed of the South Branch of Chicago River, and so into Lake Michigan.

A navigable channel has now been cut, admitting a constant flow of water from the lake, by the valley of the Des Plaines, into the Illinois. The mean discharge by this channel does not much exceed 23,000 cubic feet per minute, but it would be quite practicable to enlarge its cross-section indefinitely, and the flow through it might be so regulated as to keep the Illinois and the Mississippi at flood at all seasons of the year. The increase in the volume of these rivers would augment their velocity and their transporting power, and, consequently, the erosion of their banks and the deposit of slime in the Gulf of Mexico, while the opening of a communication between the lake and the affluents of the Mississippi, unobstructed except by locks, and the introduction of a large body of colder water into the latter, would very probably produce a considerable effect on the animal life that peoples them. The diversion of water from the common basin of the great lakes through a new channel, in a direction opposite to their present discharge, would not be absolutely without influence on the St. Lawrence, though probably this effect might be too small to be readily perceptible.*

In an able and interesting article in a California magazine, Dr. Widney has suggested a probable cause and a possible remedy for the desiccation of south-eastern California referred to in a former chapter. The Colorado Desert which lies considerably below the level of the waters of the Gulf of California, and has an area of about 4,000 square miles, evidently once formed a part of that gulf. This northern extension of the gulf appears to have been cut off from the main body by deposits brought down by the great river Colorado, at no very distant period. These deposits at the same time turned the course of the river to the south, and it now enters the gulf at a point twenty miles distant from its original outlet.

---

* From Reports of the Canal Commissioners of the State of Illinois, and especially from a very interesting private letter from William Gooding, Esq., an eminent engineer, which I regret I have not space to print in full, I learn that the length of the present canal, from the lake to the River Illinois, is 101 miles, with a total descent of a trifle more than 145 feet, and that it is proposed to enlarge this channel to the width of one hundred and sixty feet, with a minimum depth of seven, and to create a slack-water navigation in the Illinois by the construction of five dams, one of which is already completed. The descent for the outlet of the canal at La Salle on the Illinois to the Mississippi is twenty-eight feet, the distance being 230 miles. The canal thus enlarged would cost about $16,000,000, and it would establish a navigation for vessels of 1,200 to 1,500 tons burden between Lake Michigan and the Mississippi, and consequently, by means of the great lakes and the Welland canal, between the St. Lawrence and the Gulf of Mexico.

When this northern arm of the gulf was cut off from the sea, and the river which once discharged itself into it was diverted, it was speedily laid dry by evaporation, and now yields no vapor to be condensed into fog, rain, and snow on the neighboring mountains, which are now parched and almost bare of vegetation.

The ancient bed of the river may still be traced, and in floods the Colorado still sends a part of its overflowing supply into its old channel, and for a time waters a portion of the desert. It is believed that the river might easily be turned back into its original course, and indeed nature herself seems to be now tending, by various spontaneous processes, to accomplish that object. The waters of the Colorado, though perhaps not sufficient to fill the basin and keep it at the sea-level in spite of the rapid evaporation in that climate,* would at least create a permanent lake in the lower part of the depression, the evaporation from which, Dr. Widney suggests, might sensibly increase the humidity and lower the temperature of an extensive region which is now an arid and desolate wilderness.

Soil below Rock.

One of the most singular changes of natural surface effected by man is that observed by Beechey and by Barth at Lîn Tefla, and near Gebel Genûnes, in the district of Ben Gâsi, in Northern Africa. In this region the superficial stratum originally consisted of a thin sheet of rock covering a layer of fertile earth. This rock has been broken up, and, when not practicable to find use for it in fences, fortresses, or dwellings, heaped together in high piles, and the soil, thus bared of its stony shell, has been employed for agricultural purposes.[*] If we remember that gunpowder was unknown at the period when these remarkable improvements were executed, and of course that the rock could have been broken only with the chisel and wedge, we must infer that land had at that time a very great pecuniary value, and, of course, that the province, though now exhausted, and almost entirely deserted by man, had once a dense population.

---

* The thermometer sometimes rises to 120° F. at Fort Yuma, at the S. E. angle of California in N. L. 33°.

Covering Rock with Earth.

If man has, in some cases, broken up rock to reach productive ground beneath, he has, in many other instances, covered bare ledges, and sometimes extensive surfaces of solid stone, with fruitful earth, brought from no inconsiderable distance. Not to speak of the Campo Santo at Pisa, filled, or at least coated, with earth from the Holy Land, for quite a different purpose, it is affirmed that the garden of the monastery of St. Catherine at Mount Sinai is composed of Nile mud, transported on the backs of camels from the banks of that river. Parthey and older authors state that all the productive soil of the Island of Malta was brought over from Sicily.[†] The accuracy of the information may be questioned in both cases, but similar practices, on a smaller scale, are matter of daily observation in many parts of Southern Europe. Much of the wine of the Moselle is derived from grapes grown on earth carried high up the cliffs on the shoulders of men, and the steep terraced slopes of the Island of Teneriffe are covered with soil painfully scooped out from fissures in and between the rocks which have been laid bare by the destruction of the native forests.* In China, too, rock has been artificially covered with earth to an extent which gives such operations a real geographical importance, and the accounts of the importation of earth at Malta, and the fertilization of the rocks on Mount Sinai with slime from the Nile, may be not wholly without foundation.

---

[*] BARTH, *Wanderungen durch die Küsten des Mittelmeeres*, i., p. 353. In a note on page 380, of the same volume, Barth cites Strabo as asserting that a similar practice prevailed in Iapygia; but the epithet τραχεῖα, applied by Strabo to the original surface, does not necessarily imply that it was covered with a continuous stratum of rock.

[†] PARTHEY, *Wanderungen durch Sicilien und die Levante*, i., p. 404.

Valleys in Deserts.

In the latter case, indeed, river sediment might be very useful as a manure, but it could hardly be needed as a soil; for the growth of vegetation in the wadies of the Sinaitic Peninsula shows that the disintegrated rock of its mountains requires only water to stimulate it to considerable productiveness. The wadies present, not unfrequently, narrow gorges, which might easily be closed, and thus accumulations of earth, and reservoirs of water to irrigate it, might be formed which would convert many a square mile of desert into flourishing date gardens and cornfields. For example, not far from Wadi Feiran, on the most direct route to Wadi Esh-Sheikh, is a very narrow pass called by the Arabs El Bueb (El Bab) or, The Gate, which might be securely closed to a very considerable height, with little labor or expense. Above this pass is a wide and nearly level expanse, filled up to a certain regular level with deposits brought down by torrents before the Gate, or Bueb, was broken through, and they have now worn down a channel in the deposits to the bed of the wadi. If a dam were constructed at the pass, and reservoirs built to retain the winter rains, a great extent of valley might be rendered cultivable.

Effects of Mining.

The excavations made by man, for mining and other purposes, may occasion disturbance of the surface by the subsidence of the strata above them, as in the case of the mine of Fahlun, in Sweden, but such accidents have generally been too inconsiderable in extent to deserve notice in a geographical point of view.* It is said, however, that in many places in the mining regions of England alarming indications of a tendency to a wide dislocation of the superficial strata have manifested themselves. Indeed, when we consider the measure of the underground cavities which miners have excavated, we cannot but be surprised that grave catastrophes have not often resulted from the removal of the foundations on which the crust of our earth is laid. The 100,000,000 tons of coal yearly extracted from British mines require the withdrawal of subterranean strata equal to an area of 20,000 acres one yard deep, or 2,000 acres ten yards deep. These excavations have gone on for several years at this rate, and in smaller proportions for centuries. Hence, it cannot be doubted that by these and other like operations thee arth has been undermined and honey-combed in many countries to an extent that may well excite serious apprehensions as to the stability of the surface. In any event such excavations may interfere materially with the course of subterranean waters, and it has even been conjectured that the removal of large bodies of metallic ore from their original deposits might, at least locally, affect in a sensible degree the magnetic and electrical condition of the earth's crust.†

---

* MANTEGAZZA, *Rio de la Plata e Teneriffa*, p. 567.

---

* In March, 1873, the imprudent extension of the excavations in a slate mine near Morzine, in Savoy, occasioned the fall of a mass of rock measuring more than 700,000 yards in cubical contents. A forest of firs was destroyed, and a hamlet of twelve houses crushed and buried by the slide.

† The exhaustion of the more accessible deposits of coal and other minerals has compelled the miners in Belgium, England, and other countries, to carry their operations to great depths below the surface. At the colliery Des Viviers, at Cilly near Charleroi, in Belgium, coal is worked at the depth of 2,820 feet, and one pit has been sunk to the depth of 3,411 feet. It is supposed that the internal heat of the earth will render mining impossible below 4,000 feet. At Clifford Amalgamated Mines, in Cornwall, the temperature at 1,590 feet stood at 100°, but after the shaft had remained a year open it fell to 83°. In another Cornish mine men work at from 110° to 120°, but only twenty minutes at a time, and with cold water thrown frequently over them.—*The last Thirty Years in Mining Districts*, p. 95.

Stoppani mentions an abandoned mine at Huttenberg, in Bohemia, of the depth of 3,775 feet.—*Corso di Geologia*, i., p. 258.

Hydraulic Mining.

What is called hydraulic mining—a system substantially identical with that described in an interesting way by Pliny the elder, in Book XXXV. of his Natural History, as practised in his time in the gold mines of Spain[*]—is producing important geographical effects in California. Artificially directed currents of water have been long employed for washing down and removing masses of earth, but in the Californian mining the process is resorted to on a vastly greater scale than in any other modern engineering operations, and with results proportioned to the means. Brooks of considerable volume are diverted from their natural channels and conducted to great distances in canals or wooden aqueducts,[†] and then directed against hills and large level surfaces of ground which it is necessary to remove to reach the gold-bearing strata, or which themselves contain deposits of the precious mineral.[‡] Naked hills and fertile soils are alike washed away by the artificial torrent, and the material removed—vegetable mould, sand, gravel, pebbles—is carried down by the current and often spread over ground lying quite out of the reach of natural inundations, and burying it to the depth sometimes of twenty-five feet. An orchard valued at $60,000, and another estimated at not less than $200,000, are stated to have been thus sacrificed, and a report from the Agricultural Bureau at Washington computes the annual damage done by this mode of mining at the incredible sum of $12,000,000.

---

[*] I have little doubt that the hydraulic mining in Gaul, alluded to by Diodorus Siculus, *Bibliotheca Historica*, v. 27, as merely a mode of utilizing the effects of water flowing in its natural channels, was really the artificial method described by Pliny.

[†] In 1867 there were 6,000 miles (including branches) of artificial watercourses employed for mining purposes in California. The flumes of these canals are often of sheet-iron, and in some places are carried considerable distances at a height of 250 feet above the ground.—RAYMOND, *Mineral Statistics west of the Rocky Mountains*, 1870, p. 476.

[‡] The water is sometimes driven through iron tubes under a hydrostatic pressure of several hundred feet, with a force which cuts away rock of considerable solidity almost as easily as hard earth. In this way of using water, the cutting force might, doubtless, be greatly augmented by introducing sand or gravel into the current.

Accidental fires in mines of coal or lignite sometimes lead to consequences not only destructive to large quantities of valuable material, but which may, directly or indirectly, produce results important in geography. The coal is occasionally ignited by the miners' lights or other fires used by them, and certain kinds of this mineral, if long exposed to air in deserted galleries, may be spontaneously kindled. Under favorable circumstances, a stratum of coal will burn until it is exhausted, and a cavity may be burnt out in a few months which human labor could not excavate in many years. Wittwer informs us that a coal mine at St. Etienne in Dauphiny has been burning ever since the fourteenth century, and that a mine near Duttweiler, another near Epterode, and a third at Zwickau, have been on fire for two hundred years. Such conflagrations not only produce cavities in the earth, but communicate a perceptible degree of heat to the surface, and the author just quoted cites cases where this heat has been advantageously employed in forcing vegetation.

Projects of Agricultural Improvements by Duponchel.

Duponchel's schemes of agricultural improvement are so grandiose in their nature, so vast in their sphere of operation, and so important in their possible effects upon immense tracts of the earth's surface, that they must be considered as projects of geographical revolution, and they therefore merit more than a passing notice. In a memoir already quoted, and in a later work,* this engineer proposes to construct artificial torrents for the purpose of grinding up calcareous rock, by rolling and attrition along their beds, and thus reducing it into a fine slime; and at the same time these torrents are to transport an argillaceous deposit which is to be mingled with the calcareous slime, and distributed over the Landes by watercourses constructed for the purpose. By this means, he supposes that a very fertile soil may be formed, and so graded in depositing as to secure for it a good drainage.

---

* *Traité d'Hydraulique et de Géologie Agricoles*, 1868.

In order that nothing may be wanting to recommend the project, Duponchel suggests that, as some rivers of Western France are gold-bearing, it is probable that gold enough may be collected by washing the sands to reduce materially the expense of such operations.

In the Landes of Gascony alone, he believes that 3,000,000 acres, now barren, might be made productive at a moderate expense, and that similar methods might be advantageously employed in France over an extent of not less than 30,000,000 acres now almost wholly valueless.

The successful execution of the plan would increase the fertile territory of France by an area of four or five times the extent of Sicily or of Sardinia.

There seems to be no reason why the same method, applied for such different purposes, should necessarily be destructive in the one case while it is so advantageous in the other. A wiser economy might bring about a harmony of action between the miners and the agriculturists of California, and the soil which is removed by the former as an incumbrance, judiciously deposited, might become for the latter a source of wealth more solid and enduring than the gold now obtained by such a sacrifice of agricultural interests.

Action of Man on the Weather.

Espy's well-known suggestion of the possibility of causing rain artificially, by kindling great fires, is not likely to be turned to practical account, but the speculations of this able meteorologist are not, for that reason, to be rejected as worthless. His labors exhibit great industry in the collection of facts, much ingenuity in dealing with them, remarkable insight into the laws of nature, and a ready perception of analogies and relations not obvious to minds less philosophically constituted. They have unquestionably contributed essentially to the advancement of meteorological science.

The possibility that the distribution and action of electricity may be considerably modified by long lines of iron railways and telegraph wires, is a kindred thought, and in fact rests much on the same foundation as the belief in the utility of lightning-rods, but such influence is too obscure and too uncertain to have been yet demonstrated, though many intelligent observers believe that sensible meteorological effects have been produced by it.

It is affirmed that battles and heavy cannonades are generally followed by rain and thunder-storms, and Powers has collected much evidence on this subject,* but the proposition does not seem to be by any means established.

Resistance to Great Natural Forces.

I have often spoken of the greater and more subtile natural forces, and especially of geological agencies, as powers beyond human guidance or resistance. This is no doubt at present true in the main, but man has shown that he is not altogether impotent to struggle with even these mighty servants of nature, and his unconscious as well as his deliberate action may in some cases have increased or diminished the intensity of their energies. It is a very ancient belief that earthquakes are more destructive in districts where the crust of the earth is solid and homogeneous, than where it is of a looser and more interrupted structure. Aristotle, Pliny the elder, and Seneca believed that not only natural ravines and caves, but quarries, wells, and other human excavations, which break the continuity of the terrestrial strata and facilitate the escape of elastic vapors, have a sensible influence in diminishing the violence and preventing the propagation of the earth-waves. In all countries subject to earthquakes this opinion is still maintained, and it is asserted that, both in ancient and in modern times, buildings protected by deep wells under or near them have suffered less from earthquakes than those the architects of which have neglected this precaution.*

---

* *War and the Weather, or the Artificial Production of Rain*, Chicago, 1871. Paifer proposed, as early as 1814, arrangements for producing rain by firing cannon and exploding shells in the air. *Ein wunderbarer Traum die Frucht, barkeit durch willkürlichen Regen zu befördern*, Metz, 1814. See, on the question of the possibility of influencing the weather by artificial means, *London Quarterly Journal of Science*, xxix., p. 126, and *Nature*, Feb. 16, 1871, p. 306.

If the commonly received theory of the cause of earthquakes is true—that, namely, which ascribes them to the elastic force of gases accumulated or generated in subterranean reservoirs—it is evident that open channels of communication between such reservoirs and the atmosphere might serve as a harmless discharge of gases that would otherwise acquire destructive energy. The doubt is whether artificial excavations can be carried deep enough to reach the laboratory where the elastic fluids are distilled. There are, in many places, small natural crevices through which such fluids escape, and the source of them sometimes lies at so moderate a depth that they pervade the superficial soil and, as it were, transpire from it, over a considerable area. When the borer of an ordinary artesian well strikes into a cavity in the earth, imprisoned air often rushes out with great violence, and this has been still more frequently observed in sinking mineral-oil wells. In this latter case, the discharge of a vehement current of inflammable fluid sometimes continues for hours and even longer periods. These facts seem to render it not wholly improbable that the popular belief of the efficacy of deep wells in mitigating the violence of earthquakes is well founded.

In general, light, wooden buildings are less injured by earthquakes than more solid structures of stone or brick, and it is commonly supposed that the power put forth by the earth-wave is too great to be resisted by any amount of weight or solidity of mass that man can pile up upon the surface. But the fact that in countries subject to earthquakes many very large and strongly constructed palaces, temples, and other monuments have stood for centuries, comparatively uninjured, suggests a doubt whether this opinion is sound. The earthquake of the first of November, 1755, which is asserted, though upon doubtful evidence, to have been felt over a twelfth part of the earth's surface, was among the most violent of which we have any clear and distinct account, and it seems to have exerted its most destructive force at Lisbon. It has often been noticed as a remarkable fact, that the mint, a building of great solidity, was almost wholly unaffected by the shock which shattered every house and church in the city, and its escape from the common ruin can hardly be accounted for except upon the supposition that its weight, compactness, and strength of material enabled it to resist an agitation of the earth which overthrew all weaker structures. On the other hand, a stone pier in the harbor of Lisbon, on which thousands of people had taken refuge, sank with its foundations to a great depth during the same earthquake; and it is plain that where subterranean cavities exist, at moderate depths, the erection of heavy masses upon them would tend to promote the breaking down of the strata which roof them over.

---

* LANDGREBE, *Geschichte der Vulkane*, ii., pp. 19, 20.

No physicist, I believe, has supposed that man can avert the eruption of a volcano or diminish the quantity of melted rock which it pours out of the bowels of the earth; but it is not always impossible to divert the course of even a large current of lava. "The smaller streams of lava near Catania," says Ferrara, in describing the great eruption of 1669, "were turned from their course by building dry walls of stone as a barrier against them. . . . It was proposed to divert the main current from Catania, and fifty men, protected by hides, were sent with hooks and iron bars to break the flank of the stream near Belpasso.* When the opening was made, fluid lava poured forth and flowed rapidly towards Paterno; but the inhabitants of that place, not caring to sacrifice their own town to save Catania, rushed out in arms and put a stop to the operation."* In the eruption of Vesuvius in 1794, the viceroy saved from impending destruction the town of Portici, and the valuable collection of antiquities then deposited there but since removed to Naples, by employing several thousand men to dig a ditch above the town, by which the lava current was carried off in another direction.†

---

* Soon after the current issues from the volcano, it is covered above and at its sides, and finally in front, with scoriæ, formed by the cooling of the ex-

---

posed surface, which bury and conceal the fluid mass. The stream rolls on under the coating, and between the walls of scoriæ, and it was the lateral crust which was broken through by the workmen mentioned in the text.

The distance to which lava flows, before its surface begins to solidify, depends on its volume, its composition, its temperature and that of the air, the force with which it is ejected, and the inclination of the declivity over which it runs. In most cases it is difficult to approach the current at points where it is still entirely fluid, and hence opportunities of observing it in that condition are not very frequent. In the eruption of February, 1850, on the east side of Vesuvius, I went quite up to one of the outlets. The lava shot out of the orifice upwards with great velocity, like the water from a fountain, in a stream eight or ten feet in diameter, throwing up occasionally volcanic bombs three or four feet in diameter, which exploded at the height of eight or ten yards, but it immediately spread out on the declivity down which it flowed, to the width of several yards. It continued red-hot in broad daylight, and without a particle of scoriæ on its surface, for a course of at least one hundred yards. At this distance, the suffocating, sulphurous vapors became so dense that I could follow the current no farther. The undulations of the surface were like those of a brook swollen by rain. I estimated the height of the waves at five or six inches by a breadth of eighteen or twenty. To the eye, the fluidity of the lava seemed as perfect as that of water, but masses of cold lava weighing ten or fifteen pounds floated upon it like cork.

The heat emitted by lava currents seems extremely small when we consider the temperature required to fuse such materials and the great length of time they take in cooling. I saw at Nicolosi ancient oil-jars, holding a hundred gallons or more, which had been dug out from under a stream of old lava above that town. They had been very slightly covered with volcanic ashes before the lava flowed over them, but the lead with which holes in them had been plugged was not melted. The current that buried Mompiliere in 1669 was thirty-five feet thick, but marble statues, in a church over which the lava formed an arch, were found uncalcined and uninjured in 1704. See SCROPE, *Volcanoes*, chap. vi. § 6.

* FERRARA, *Descrizione dell' Etna*, p. 108.

† LANDGREBE, *Naturgeschichte der Vulkane*, ii., p. 82.

Incidental Effects of Human Action.

I have more than once alluded to the collateral and unsought consequences of human action as being often more momentous than the direct and desired results. There are cases where such incidental, or, in popular speech, accidental, consequences, though of minor importance in themselves, serve to illustrate natural processes; others, where, by the magnitude and character of the material traces they leave behind them, they prove that man, in primary or in more advanced stages of social life, must have occupied particular districts for a longer period than has been supposed by popular chronology. "On the coast of Jutland," says Forchhammer, "wherever a bolt from a wreck or any other fragment of iron is deposited in the beach sand, the particles are cemented together, and form a very solid mass around the iron. A remarkable formation of this sort was observed a few years ago in constructing the sea-wall of the harbor of Elsineur. This stratum, which seldom exceeded a foot in thickness, rested upon common beach sand, and was found at various depths, less near the shore, greater at some distance from it. It was composed of pebbles and sand, and contained a great quantity of pins, and some coins of the reign of Christian IV., between the beginning and the middle of the seventeenth century. Here and there, a coating of metallic copper had been deposited by galvanic action, and the presence of completely oxydized metallic iron was often detected. Investigation made it in the highest degree probable that this formation owed its origin to the street sweepings of the town, which had been thrown upon the beach, and carried off and distributed by the waves over the bottom of the harbor."[*] These and other familiar observations of the like sort show that a sandstone reef, of no inconsiderable magnitude, might originate from the stranding of a ship with a cargo of iron,* or from throwing the waste of an establishment for working metals into running water which might carry it to the sea.

---

[*] *Geognostische Studien am Meeres Ufer*, LEONHARD und BRONN, *Jahrbuch*, 1841, pp. 25, 26.

Parthey records a singular instance of unforeseen mischief from an interference with the arrangements of nature. A landowner at Malta possessed a rocky plateau sloping gradually towards the sea, and terminating in a precipice forty or fifty feet high, through natural openings in which the sea-water flowed into a large cave under the rock. The proprietor attempted to establish salt-works on the surface, and cut shallow pools in the rock for the evaporation of the water. In order to fill the salt-pans more readily, he sank a well down to the cave beneath, through which he drew up water by a windlass and buckets. The speculation proved a failure, because the water filtered through the porous bottom of the pans, leaving little salt behind. But this was a small evil, compared with other destructive consequences that followed. When the sea was driven into the cave by violent west or north-west winds, it shot a *jet d'eau* through the well to the height of sixty feet, the spray of which was scattered far and wide over the neighboring gardens and blasted the crops. The well was now closed with stones, but the next winter's storms hurled them out again, and spread the salt spray over the grounds in the vicinity as before. Repeated attempts were made to stop the orifice, but at the time of Parthey's visit the sea had thrice burst through, and it was feared that the evil was without remedy.†

I have mentioned the great extent of the heaps of oyster and other shells left by the American Indians on the Atlantic coast of the United States. Some of the Danish kitchen-middens, which closely resemble them, are a thousand feet long, from one hundred and fifty to two hundred wide, and from six to ten high. These piles have an importance as geological witnesses, independent of their bearing upon human history.

---

* KOHL, *Schleswig-Holstein*, ii., p. 45.

† *Wanderungen durch Sicilien und die Levante*, i., p. 406.

Wherever the coast line appears, from other evidence, to have remained unchanged in outline and elevation since they were accumulated, they are found near the sea, and not more than about ten feet above its level. In some cases they are at a considerable distance from the beach, and in these instances, so far as yet examined, there are proofs that the coast has advanced in consequence of upheaval or of fluviatile or marine deposit. Where they are altogether wanting, the coast seems to have sunk or been washed away by the sea. The constancy of these observations justifies geologists in arguing, where other evidence is wanting, the advance of land or sea respectively, or the elevation or depression of the former, from the position or the absence of these heaps alone.

Every traveller in Italy is familiar with Monte Testaccio, the mountain of potsherds, at Rome;* but this deposit, large as it is, shrinks into insignificance when compared with masses of similar origin in the neighborhood of older cities. The castaway pottery of ancient towns in Magna Græcia composes strata of such extent and thickness that they have been dignified with the appellation of the ceramic formation. The Nile, as it slowly changes its bed, exposes in its banks masses of the same material, so vast that the population of the world during the whole historical period would seem to have chosen this valley as a general deposit for its broken vessels.

The fertility imparted to the banks of the Nile by the water and the slime of the inundations, is such that manures are little employed. Hence much domestic waste, which would elsewhere be employed to enrich the soil, is thrown out into vacant places near the town. Hills of rubbish are thus piled up which astonish the traveller almost as much as the solid pyramids themselves. The heaps of ashes and other household refuse collected on the borders and within the limits of Cairo were so large, that the removal of them by Ibrahim Pacha has been looked upon as one of the great works of the age.

---

* Until recently this hillock was supposed to consist of sherds of household pottery broken in using, but it now appears to be ascertained that it is composed of fragments of earthenware broken in transportation from the place of manufacture to the emporium on the Tiber where such articles were landed.

These heaps formed almost a complete rampart around the city, and impeded both the circulation of the air and the communication between Cairo and its suburbs. At two points these accumulations are said to have risen to the incredible height of between six and seven hundred feet; and these two heaps covered two hundred and fifty acres.[*] During the occupation of Cairo by the French, the invaders constructed redoubts on these hillocks which commanded the city. They were removed by Mehemet Ali, and the material was employed in raising the level of low grounds in the environs.[†]

In European and American cities, street sweepings and other town refuse are used as manure and spread over the neighboring fields, the surface of which is perceptibly raised by them, by vegetable deposit, and by other effects of human industry, and in spite of all efforts to remove the waste, the level of the ground on which large towns stand is constantly elevated. The present streets of Rome are twenty feet, and in many places much more, above those of the ancient city. The Appian Way between Rome and Albano, when cleared out a few years ago, was found buried four or five feet deep, and the fields along the road were elevated nearly or quite as much. The floors of many churches in Italy, not more than six or seven centuries old, are now three or four feet below the adjacent streets, though it is proved by excavations that they were built as many feet above them.[‡]

---

[*] CLOT BEY, *Égypte*, i., p. 277.

[†] Egypt manufactures annually about 1,200,000 pounds of nitre, by lixiviating the ancient and modern rubbish-heaps around the towns.

[‡] Rafinesque maintained many years ago that there was a continual deposition of dust on the surface of the earth from the atmosphere, or from cosmical space, sufficient in quantity to explain no small part of the elevation referred to in the text. Observations during the eclipse of Dec. 22, 1870, led some astronomers to believe that the appearance of the corona was dependent upon

Nothing Small in Nature.

It is a legal maxim that "the law concerneth not itself with trifles," *de minimis non curat lex;* but in the vocabulary of nature, little and great are terms of comparison only; she knows no trifles, and her laws are as inflexible in dealing with an atom as with a continent or a planet.* The human opera-

---

or modified by cosmical dust or matter in a very attenuated form diffused through space.

Tyndall has shown by optical tests that the proportion of solid matter suspended or floating in common air is very considerable, and there is abundant other evidence to the same purpose. Ehrenberg has found African and even American infusoria in dust transplanted by winds and let fall in Europe, and Schliemann asserts that the quantity of dust brought by the scirocco from Africa is so great, that by cutting holes in the naked rocks of Malta enough of Libyan transported earth can be caught and retained, in the course of fourteen years, to form a soil fit for cultivation.—*Beilage zur Allgemeinen Zeitung,* Mar. 24, 1870.

* One of the sublimest, and at the same time most fearful suggestions that have been prompted by the researches of modern science, was made by Babbage in the ninth chapter of his *Ninth Bridgewater Treatise.* I have not the volume at hand, but the following explanation will recall to the reader, if it does not otherwise make intelligible, the suggestion I refer to:

No atom can be disturbed in place, or undergo any change of temperature, of electrical state, or other material condition, without affecting, by attraction or repulsion or other communication, the surrounding atoms. These, again, by the same law, transmit the influence to other atoms, and the impulse thus given extends through the whole material universe. Every human movement, every organic act, every volition, passion, or emotion, every intellectual process, is accompanied with atomic disturbance, and hence every such movement, every such act or process, affects all the atoms of universal matter. Though action and reaction are equal, yet reaction does not restore disturbed atoms to their former place and condition, and consequently the effects of the least material change are never cancelled, but in some way perpetuated, so that no action can take place in physical, moral, or intellectual nature, without leaving all matter in a different state from what it would have been if such action had not occurred. Hence, to use language which I have employed on another occasion: there exists, not alone in the human conscience or in the omniscience of the Creator, but in external nature, an ineffaceable, imperishable record, possibly legible even to created intelligence, of every act done, every word uttered, nay, of every tions mentioned in the last few paragraphs, therefore, do act in the ways ascribed to them, though our limited faculties are at present, perhaps forever, incapable of weighing their immediate, still more their ultimate consequences. But our inability to assign definite values to these causes of the disturbance of natural arrangements is not a reason for ignoring the existence of such causes in any general view of the relations between man and nature, and we are never justified in assuming a force to be insignificant because its measure is unknown, or even because no physical effect can now be traced to it as its origin. The collection of phenomena must precede the analysis of them, and every new fact, illustrative of the action and reaction between humanity and the material world around it, is another step towards the determination of the great question, whether man is of material nature or above her.

---

wish and purpose and thought conceived by mortal man, from the birth of our first parent to the final extinction of our race; so that the physical traces of our most secret sins shall last until time shall be merged in that eternity of which not science, but religion alone. assumes to take cognizance.

INDEX.

- ABSORPTION of moisture by earth, amount of, uncertain, 22
- ADIRONDACKS, forest, geographical importance of, 327
  - lakes of, 433
- AFRICA, Northern, artesian wells in, 478–482
  - desert of, atmosphere and scenery in, 572
- AGRICULTURE of the United States, products of, 73
- AKABA, fresh water on sea-beach at, 477, *note*
- ALBANO, lake of, artificial lowering of, 427
- AMERICA, NORTH, primitive physical condition of, 17.
  - scientific observation of its physical changes, 44
  - forests of, 326 *et seqq.*
  - forest trees of, compared with European, 334–342
  - dunes of, 575
  - hydrographical improvements in, 625–627
- ANIMALCULÆ, or infusorial life, importance of, 145–147
- ANIMALS, WILD, sympathy of ruder races with, 38, *note*
  - wild, instinct, modification of, 39, *note*
  - large marine, unimportant in geography, 96
  - extinction of, 105
  - domestic, origin and transfer of, 86
- ANIMAL LIFE, as geographical agency, 80
  - remains of, volume of, 80, *note*
  - extirpation of, by man, 91, *note*
- APENNINES, effects of felling woods of, 153
- APPIAN WAY, the level of, raised, 642
- AQUATIC PLANTS, action of, in raising level of marshes, 30, *note*
- AQUEDUCTS, geographical and climatic effects of, 446
- ARABIA PETRÆA, sandstone of, 483, *note*; 546, *note*
  - sands and petrified wood of, 548, *note*
- ARAGUA, valley of, 220
- ARDÈCHE river, floods of, 256–262
- ARGOSTOLI, subterranean marine currents at, 470, *note*
- ARMIES, introduction of foreign vegetables by, 69
- ARNO, floods of, 539, *note*
- ARTESIAN WELLS, ascent of fluids in, 476 *et seqq.*
  - ancient, 478, *note*
  - in Algeria, 478–481
  - at St. Louis, 480, *note*
  - deepest, 480, *note*
- AUK, the wingless, extirpation of, 122
- AUSTRALIA, as field of physical observation, 51
- AVALANCHES, trees as protection against, 290

- BABINET'S plan for artificial springs, 485, 486
- BAVARIA, scarcity of fuel in, 323, *note*
- BEAVER, action of, in producing bogs, 83
  - constructs canals, 83, *note*
  - cause of increased numbers of, 92
- BEE-HONEY, introduction of, into the United States, 136
- BEE-HUSBANDRY in Italy, 136, *note*
- BERGAMO, change of climate in the vicinity of, 164, *note*
- BIRDS, geographical importance of, 111
  - introduction of foreign, 113
  - destruction of, 115–125
  - how far useful or injurious by preying on insects, 119, *note*
  - migration of, 120, 121
  - seek shelter from cold under snow, 212, *note*
- BISON, domestication of, 88, 390, *note*
  - numbers of, in the United States, 90, *note*
  - numbers of, annually destroyed, 95
- BLASTS, powder, remarkable, 403, *note*
- BOGS, floating, 29
  - quantity of, 28, *note*
  - how formed, 29
  - formation of, by beavers, 83

BOURGET Lake, importance of, as a basin of reception, 495
BRÉMONTIER'S system of dune plantations, 594
BRETON, Cap, dune vineyards of, 598
BUSBEQUIUS'S letters, value of, 65

CAMEL, introduction of, into Europe and America, 87, 88
  injurious to vegetation in desert, 151
CAMPINE in Belgium, 607
CANADA THISTLE, 70
CANALS, effects of, in interchanging organic life, 97
  excavations for, 403, *note*
  and aqueducts, climatic and geographical effects of, 446
  of Tuscany, injurious effects of, 447, *note*
  of the Ganges, 452, *note*
  marine, 610
  across Isthmus of Darien, 612
  Suez, 78, 612
  across Isthmus of Corinth, 614
  between Mediterranean, Red Sea, and Dead Sea, 616
  between North Sea and Baltic, 618
  between North Sea and Zuiderzee, 619
  across Cape Cod, 619
  between Don and Volga, 621
  between Erie and Genesee, 626
  between Lake Michigan and the Illinois, 626
CAPE COD, sand dunes of, 580, *note*
CAPPERCAILZIE, extinction and reintroduction of, in Great Britain, 123
  habits of, 123, *note*
CAPRIFICATION, whether useful, 129, *note*
CARNIOLA, caves of, 490, *note*
CASPIAN, natural and artificial changes in, 325, *note;* 620
CATANIA, lava streams at, 637
CAULIFLOWERS, fresh, supplied by Algeria to Northern Germany, 65, *note*
CELANO Lake, draining of, by Prince Torlonia, 429
CHERBOURG, breakwater at, 402
CEREALS, self-propagating in California, 60, *note*
CEVENNES, effects of clearing the, 166
CHAMOIS, numbers of killed, 95
CHESTNUT crop in France and Tuscany, value of, 337, *note*
CHIANA, Val di, character of, 532
  improvements in, 533, 534
CICERO, his opinion of merchants, 7, *note*
  his opinion of the mechanical arts, 427, *note*
CINCHONA, introduction of, into India, 60, *note*
  improved by cultivation, 60, *note*
CLIMATES, ancient, character of, uncertain, 15
  causes producing change in New England, 21, *note*
COAL, early use of, for fuel, 308, *note*
  increased use of, in Paris, 359, *note*
  extracted in England, quantity of, 631
COAST-LINE, change of, from natural causes, 399
  subject to human guidance, 400, 401
COCHINEAL insect transferred to Spain, 136
COMMERCE, discouraged and despised by ancient Romans, 7, 65, *note;* 614
  modern, objects of, 63
COMO, Lake of, proposed lowering of, 433, *note*
  effect of lowering on stability of shores and percolation, 433, *note*
  percolation of water from, 433
  importance of, as basin of reception, 494
CONSTANCE, Lake of, diversion of Rhine from, 625
CONSTANTINOPLE, water supply of, 349, *note;* 446, *note*
COPAIS Lake, draining of, 427
CORK Tree, yield of, 328, *note*
CORPORATIONS, industrial and financial, corruption and demoralizing effects of, 58, *note*
COTTON-SEED, value of, 36, *note*
  introduction of, into U. S., 74, *note*
CRAU, reclamation of, 162, *note*
CYPRESS Tree, its beauty, 342

DARIEN Isthmus, proposed canal across, 612
DEAD SEA, projected canal to, 616
DEER, tame, injurious to trees, 383, *note*
  number of, in the United States, 91
DELTA, of the Mississippi, 503, *note*
  of the Ganges, 503, *note*
  of the Hoang-ho, 503, *note*
DENMARK, peat mosses of, 31, *note*
DEPOSITS of rivers, geological importance of, 399
  marine, on coast of Netherlands, 410
  of rivers of Tuscany, 525
DESERT Trees, propagation of, 151
  Arabian, scenery of, 483, *note*
DESPOTISM a cause of physical decay, 5
DESICCATION, secular, of soil, 20, *note*
DIKES, Sea, origin of, 405
  of Netherlands, 407 *et seqq.*
  construction of, 413
  in Egypt, 455
  of Mississippi, 511
  See Embankments.

- Dinornis or Moa, recent extirpation of, in New Zealand, 122
- Diseases, contagious, propagation of, by germs, 147, *note*
- Dodo, extirpation of, 122
- Don River, proposed diversion of, 621
- Drainage of Lakes, 417
  - of Lake of Haarlem, 418
  - of Lake of Albano, 427
  - of Lake of Fucinus or Celano, 429
  - of Lake of Copais, 369
  - of Lake of Lungern, 433
  - of bogs and swamps, 435 *et seqq.*
  - its necessity in lands newly reclaimed from forest, 437
  - surface and subterranean, and their effects, 438
  - by boring, 439
  - of surface waters, climatic effects of, 440
  - unforeseen effects of, 445
  - effect of, on inundations, 489
- Drance, glacier lake of, 500
- Dugdale on sea dikes, 406, *note*
- Dunes, coast, how formed, 559 *et seqq.*
  - height of, 562
  - sands of, character and composition of, 567, 600, *note*
  - interior structure of, 569
  - stratification of, 570
  - geological importance of, 572
  - of American coasts, 575
  - of Western Europe, 575
  - age, character, and permanence of, 577
  - naturally wooded, 579
  - protection of, 580, 592
  - uses of, as a barrier against the sea, 581
  - movement of, 587
  - control of, by man, 591
  - artificial, 591
  - plantation of, 594 *et seqq.*
  - vineyards upon, 595
  - artificial removal of, 599
  - inland, 600
    - of North American Desert, 600
    - of South American Desert, 601
- Duponchel, proposals for agricultural improvement, 633
- Durance, fertilizing slime of, 245, *note*
- Dust, cosmical, deposit of, 642, *note*
- Dwight, Dr., travels in the United States characterized, 51, *note*

- Earth, habitable, generally wooded, 148
  - displacement of, in engineering, 403, *note*
  - transported to cover rocky surface, 629
- Earthquakes, resistance to, 635
- Earthworms, utility of, 129-131
- Eels, destruction of, 107, *note*
- Egypt, introduction of foreign plants and animals into, 67, *note*
  - catacombs of, 81, *note*
  - papyrus and water-lily of, 77, *note*
  - poisonous snakes of, 126, *note*
  - supposed increase of rain in, 197, *note*
  - productiveness of, 244, *note*
  - original condition of, 449
  - amount of water used for irrigation, 450
  - cultivated soil of, 453
  - population of, 454
  - originally morass, 455, *note*
  - saline deposits of, 468
  - sands of, 552
  - their prevalence and extent, 555, *note*
  - action on the Delta and cultivated land, 554
  - source of sands, 555
  - effect of diversion of the Nile upon, 622
  - refuse heaps near Cairo, 641, *note*
- Elephant, numbers of, killed, 94
- Elsineur, artificial formation in harbor of, 639
- Embankments, river, uses and evils of, 501 *et seqq.*
  - imitation of nature, 531, *note*
  - Lombardini's views of, 502, *note*
  - of Mississippi, magnitude of, 511
- Engineers and Artisans, not respected by ancients or in Middle Ages, 426
- England, forest economy of, 307
  - forests of, described by Cæsar, 309, *note*
  - large extent of ornamental plantation, 309
  - private enterprises in sylviculture, 311
- Enguerrand de Coucy, cruelty of, 350
- Etna, eruptive matter of, infertile, 150
- Eucalyptus, growth and height of, 334, *note*; 394, *note*
- Euphrates, sand plains in the valley of, 604
- Evaporation, amount of, uncertain, 24
  - from forest earth, 176
  - relative, from earth and water, 441, *note*
- Evergreen Trees, properties of, 175, *note*; 205, 207
- Eye, cultivation of, 11
  - sympathy between, and other organs, 11, *note*

- Fens of Lincolnshire, draining of, 403
- Feudalism, abuses of, 5, *note*
- Fire, action of, on wood-land, 361, 362
  - protection of woods against, 384

    forest, of 1871, 385
    measures against, 386
FIR-TREE, cicatrization of stump, 338, *note*
FIRE-WEED in burnt forests of the United States, 295
FISH, introduction and breeding of, 97–101
    naturalization of, 97
    destruction of, 101 *et seqq.*
    spawn consumed by water-fowl, 101
    inferiority of artificially fattened, 108
    fresh water, growing scarcity of, in United States, 108, *note*
    shell, extensive heaps of remains of in United States, 97
    shell, extensive heaps of remains of, Indian origin, 97
FISH PONDS, in Catholic countries, 529, *note*
FISHERIES of the world, annual yield of, 103 *et seqq.*, *note*
FOG rare in woods, 192, *note*
FONTAINEBLEAU, forest of, 105
    forest of, its renovation, 373, *note*
    soil of, 607, *note*
FORCES, natural, accumulation of, 37
FORESTS, royal, 349–354
    See Woods.
FOREST LAWS, Jewish, 348, *note*
    severity of, in France and England, 350
    under Louis IX., 351
    mediæval character of, 386
    of America, created by circumstances, 388
FRANCE, the peasantry of, described by La Bruyère, 6, *note*
    the peasantry of, described by Arthur Young, 6, *note*
    forests of, 312
    imports timber largely, 314, *note*
    sale of forest lands by, 315
    recent forest legislation of, highly useful, 317
    royal forests and forest laws, 349
    inundations of, 489
    remedies against inundations, 490
FRESCOBALDI on sands of desert, 551, *note*
FRIESLAND, sand dunes of, 588
FROST, action of, on soil, 416, *note*
FUCINUS, draining of Lake of, by Prince Torlonia, 429 *et seqq.*
FUR Animals, destruction of, 106, *note*

GAME Laws, effects of, 96, *note*; 117, 311, 352
GANGES, effect of clearing valley of, 399, *note*
    canal, 452, *note*
GASCONY, coast sands of, 576
    dunes, 576
    dunes, extent and advance of, 576
    landes of, 606
        their reclamation, 606
        their area, 611
GERMAN Ocean, sands of, 548, *note*
GEOGRAPHY, modern, embraces organic life, 56
GLACIER lakes in Switzerland, 500
GOAT, Angora, habits of, 89, *note*
    introduction of, into America, 89, *note*
GOLDAU, Switzerland, mountain slide at, 287
GOLD FISH, the introduction of, from China, 97
GRAPE disease, its economic effects in France, Italy, Sicily, 79
GRASS-LAND, meteorological action of, 55
GRAVE-DIGGER beetle, habits of, 131
GREECE, subterranean waters of, 470, *note*
    proposed canal through Isthmus of Corinth, 613
    proposed canal across Mt. Athos, 615
GULLS, sea, habits of, 114, *note*
GUNPOWDER, chiefly used for industrial purposes, 406, *note*

HAARLEM, Lake of, drained, 418
    climatic effect of drainage, 443
HAIL, whether prevented by woods, 155, *note*
HARBORS, artificial, rarity of, 401, *note*
HAURAN, the productions of its soil, 60, *note*
HEAT, solar, utilization of, 46, *note*
        action of, on rock, 551, *note*
HEILBRONN, springs of, 226
HERRING, fishery of, 107, *note*
HESSIAN FLY, introduction of, into the United States, 134
HOANG-HO, delta of, 277
    change of mouth of, 503, *note*
HUMAN action, incidental effects of, 629 *et seqq.*
HUMPHREYS & ABBOT'S Report on the Mississippi, value of, 510, *note*
HYDROGRAPHY of North America, 625

IBIX, the Alpine, 94
IJSSEL river, 423
IMPROVEMENT, works of, remarkable for volume and difficulty, 402, *note*
INDIA, devastation of forests in, 311, *note*
INDIAN CORN, acclimation of, 18, *note*
INDIANS on Amazon, their skill in the use of the bow, 13, *note*
INFILTRATION of water from lakes, 423, *note*
    of fresh water in Gulf of Akaba, 477, *note*
    of Nile water, 475, *note*
INFUSORIÆ, importance of, 141–147

INSECTS and worms, utility of, 134
useful in fertilization of plants, 125 *et seqq.*
influence of, on vegetation, 132–137
carnivorous, useful to man, 135
how far injurious to forest trees, 132
introduction of, 134–135
ravages of, 136
tenacity of life in, 137 *et seqq.*
destruction of, by fish, 138
abundance of, in Northern Europe, 138, *note*
destruction of, by birds, 113
quadrupeds, 140
confine themselves to dead trees, 140, 381, *note*
do not multiply in the forest, 343
INSTINCT, animal, modification of, 39, *note*
INSURANCE against fall of rocks, 292, *note*
forest fires, 386
INUNDATIONS, recent measures against, 509
aggravated by deposits in bed of streams, 237
occasioned by thaws, 239
in France, history of, 243, *note*
economical evils of, 244
action of, on river bed, 261
in Netherlands, 404
and torrents, 488 *et seqq.*
of 1856 in France, 489
measures against, in France, 491
where they originate, 491
remedies against, 493
from ice barriers, 500
of banks of river Po, 509, *note*
Rozet's remedy against, 512
IRRIGATION, antiquity of, 448
among Mexicans and Peruvians, 448, *note*
its necessity in hot climates, 449
in Northern Italy, 456, *note*
in Turkish Empire, 450
in India, 452
in Egypt, 453
in the United States, 457, *note*
in Italy, 458, *note*
in Spain, 459, *note*
quantity of water used in, 456, 465, *note*
difficulties of, 459, *note*
effects of, on vegetable crops, 459, *note*
climatic effects of, 460
recovery of water employed in, 465
effects of, on river supply, 465
deposit of salt by, 467
ISLANDS, floating, 419, *note*
ITALY, beauty of its winter scenery, 215
effect of the denudations of its forests, 263, *note*
extent of irrigation in, 457
sky of, 464, *note*

JOHNSTRUP'S observation on absorption of moisture by earth, 216, *note*
JUPITER, satellites of, visible to the naked eye, 14, *note*
JUTLAND, destruction of forests in, 348, *note*
encroachments of the sea on, 583

KANDER river, artificial course of, 499
KARST, plantations on, 324, *note*
subterranean waters of, 470, *note*
KJÖKKENMÖDDINGER, heaps of kitchen refuse, 16

LAKES, draining of, 417
natural process of filling up, by aquatic vegetation, 419, *note*
lowering of, in ancient and modern times, 428 *et seqq.*
draining of, in Switzerland, 432, *note*
effects of, 432, *note*
mountain, their disappearance, 433
their utility, 435
LAND won from the waters, 398 *et seqq.*
LÆSTADIUS, account of Swedish Laplanders, 123, *note*
LIFE, American, instability of, 396
balance of animal and vegetable, 145
LIIMFJORD, irruption of sea into, 583 *et seqq.*
aquatic vegetation of, 584
original state of, 610
LIMA and Sestajone rivers compared, 238, *note*
LION, an inhabitant of Europe, 92, *note*
LISBON, earthquake of, 637
LOCUST does not breed in woods, 299
LOMBARDINI on precipitation, 463, *note*
on Tiber, 474
on river embankments, 502, *note*
on elevation of bed of Po, 507, *note*
Guida allo Studio dell' Idrologia, 510, *note*
on inundations, 515, *note*
on Val di Chiana, 534
LOMBARDY, climate of, 456
statistics of irrigation in, 459
LOUIS IX. of France, misguided clemency of, 351
LUMBER trade of Quebec, 360, *note*
the United States, 360, *note*
augmented consumption of, 356, *note*
LUNGERN, Lake of, lowering, 433

MADAGASCAR, gigantic bird of, 123
MADDER, cultivation of, in France, 19, *note*

Maggiore, Lake of, importance of, as basin of reception, 495
Magnitude, unit of, nature has none, 145
Maize, acclimation of, 18, *note*
Malta, transported soil of, 629
Man, reaction of, on nature, 8
  action of, on organic life, 10, *note*
   measurement of influence of, uncertain, 14
  destructiveness of, 33, 35, *note;* 36–41
  first conquests over nature, 38, *note*
  geographical action of, compared with that of brutes, 41
  physical improvement by, 44
  limits of his physical power, 45
  remains of, contemporary with mammoth, 82, *note*
  agency of, in extirpation of fish, 101
   of aquatic animals, 105
   of birds, 116–129
  possible control of minute organisms by, 140 *et seqq.*
  possible geographical changes by, 609 *et seqq.*
  incidental effects of his action, 639 *et seqq.*
  action of, illimitable and never-ending effects of, 643, 644
Marcite of Lombardy, 461, *note*
Maremma, Tuscan, improvements in, 528 *et seqq.*
Marshes, how far unhealthy, 158, *note*
  draining of, in Italy, 436
   United States, 437
   climatic action of, 440
  insalubrity of mixture of salt and fresh water in, 527, *note*
Matches, Lucifer, 356, *note*
Mechanic arts, illustration of their mutual interdependence, 370, *note*
  despised by ancient Romans and in Middle Ages, 427, *note*
  not respected in Modern Italy, 427, *note*
Medanos or dunes of the South American Desert, 601, 602
Mediterranean Sea, not rich in organic life, 98
  sands of, 549
  tides of, 564
Mella river, change in character of, 264, *note*
Mengotti on Nile, 516
Meteorology, uncertainty of this science, 22
  nomenclature of, vague and equivocal, 23, *note*
Metrical system, French, objections to, 146, *note*
Mexico, Desaguadero at, 402, *note*
Michigan, Lake, sand dunes of, 564
  sand dunes of, originally wooded, 579 *et seqq.*
  diversion of its waters, 626
Mines, adits of, 403, *note*
  excavations for, 630
  depth of greatest, 631, *note*
  fires in, 633
Mining, effects of, 630
  hydraulic, 632
   practised by ancients, 632
Miramichi, great fire of, 27, *note*
Mississippi, alleged increase in volume of, 229, *note*
  discharge of, 472, 519, *note*
  delta of, 501, *note*
  levées of, 511
  cut-offs and their effects, 514
  sediment of, 521, *note;* 543, *note*
  precipitation in the valley of, 519, *note*
Mistral, noticed by Diodorus Siculus, 165, *note*
Monasteries, evil effects of, 5, *note*
Moose deer, the American, rapid multiplication of, 388, *note*
Morgan, L. H., on the American beaver, 84, *note*
Monte Testaccio, 641
Mt. Cenis, excavations for, 403, *note*
  gunpowder used in, 403, *note*
Mosses and fungi, uses of, 233, *note*
Mountains as reservoirs of water, 215
Mountain slides, their cause, 284
  woods, as protection against, 290
Mushrooms, poisonous, how to render harmless, 294, *note*

Natural Bridge in Virginia, disappearance of river at, 473, *note*
Natural forces, accumulation of, 43
  resistance to, 635
Nature, its action on man, 7
  man's reaction on, 8
  observation of, 11
  geographical stability of, 26–31
  restoration of disturbed harmonies of, 48
  nothing insignificant in, 643
Netherlands, ancient inundations of, 404
  recovery of land by diking in, 404, 405
  extent of land gained from sea, 407
   lost by incursion of sea, 408
  character of land gained by, 409
  natural process of recovery, 410–412
  method of construction of dikes, 413
  modes of protection of coasts in, 414, *note*
  effect of diking on the level of the land, 415
  drainage, 415, *note*, *et seqq.*

    effects on the social, moral, and economic interests of the people, 424
  coast improvements in, 542
  sand dunes of, 581
  encroachments of the sea on, 583 *et seqq.*
  artificial dunes in, 591
  removal of dunes in, 587
NILE, its ancient state, 453, 454
  infiltration of water of, 476, *note*
  artificial mouths of, 599
  inundations of, 516
  embankments of, 516 *et seqq.*
  mud banks caused by its deposits, 517
  discharge of, 519, *note*
  sediment of, 478, *note*; 524, *note*
  sand dunes at its mouth, 564
  proposed diversion of, 621
  effects of, 623
  ceramic banks of, 641
NOLLA torrent, 264, *note*
NORWAY, exports lumber to India, 305, *note*
NUMBERS, misleading effects of too definite statement of, 283, *note*
NUTMEG transported by birds, 112, *note*

OAK, the English, early uses in the arts, 310, *note*
  openings in North America, 345, *note*
OBSERVATION, power of, cultivated, 51-55
OHIO, mounds of, 18
  remains of a primitive people in, 363, *note*
OILS, importance of, in modern commerce, 63
OLD WORLD, physical decay of, 3
  former populousness of, 4
  present desolation of, 4
  its causes, 5
  ancient climate of, 15
  physical restoration of, 48 *et seqq.*
OLIVE TREE, the wild, 61, *note*
  importance of, 339, *note*
  cultivation of, in Italy, 340, *note*
ORANGE, when first known in Europe, 66
ORCHIDS, fertilization of, by insects, 132
ORGANIC LIFE embraced in modern geography, 56 *et seqq.*
  its geological agency, 80 *et seqq.*
  geographical importance of, 82
ORGANISMS, minute, importance of, 140-144
OSTRICH, the, diminution of its numbers, 123
OTTAQUECHEE river, Vermont, transporting power of, 275
OTTER, the American, voracity of, 106
OYSTER, the, transplantation of, 100

PALESTINE, ancient terrace culture and irrigation of, 450
  disastrous effects of its neglect, 451
PALISSY on artificial springs, 484 *et seqq.*
PARAGRANDINI, of Lombardy, 154, *note*
PARAMELLE, the Abbé of, on fountains, 474
PAULOWNIA, rapid growth of, 395, *note*
PEAT unknown as fuel to Greeks, Romans, and High German tribes, 29, *note*
  used anciently by Low German tribes, 29, *note*
PEAT MOSSES of North Sjaelland, fossil wood in, 31, *note*
PECORA, river of the Maremma, its deposits, 528, *note*
PENGUIN, destruction of, 124, *note*
PERU, ancient progress in the arts, 448
  basins of reception in, 496
PETRA, water at, 466, *note*
PETROLEUM, quantity of, 49, 323, *note*
  ascent of, in artesian wells, 478, *note*
PHOSPHORESCENCE of the sea, not noticed by ancients, 104
PHYSICAL DECAY of the earth's surface, 3 *et seqq.*
  its causes, 5
  forms and formations predisposing to, 31
  arrest of, in new countries, 44
PHYSICAL GEOGRAPHY, study of, recommended, 13
PHYSICAL IMPROVEMENTS, important, chapter on, 609-642
PHYSICAL RESTORATION of disturbed harmonies, 31
  of the earth, 44 *et seqq.*
  of the Old World, 44
PINE, the American, former ordinary dimensions of, 330
  the white, rapidity of its growth, 330, *note*
  umbrella, the most elegant of trees, 336
  the maritime, on dune sands in France, 337, 596, 606
  how affected by accidents of its growth, 369
PINUS CEMBRA of Switzerland, 336
PISCICULTURE, its valuable results, 99
  See Fish.
PLANTS, cultivated, uncertain identity of ancient and modern, 19
  changes of habits of, by domestication, 21
  geographical influences of, 56
  domestic, origin of, 58, 59
  modes of introduction of, 65
  accidental introduction of, 68
  how affected by transfer, 69
  tenacity of life in wild species, 69
  power of accommodation of, 70
  foreign, grown in United States, 71
  American, grown in Europe, 76

  extirpation of, 76
  wild American, extirpation of, 78
PO, sediment of, 276–284
  floods of, in 1872, 279, *note*
  embankments of, 507 *et seqq.*
  geographical character of, 507, *note*
  inundations of, 509, *note*
  discharge of, 519, *note*
PONDS, objections to draining, in Catholic countries, 529, *note*
POWDER, consumption and uses of, 406, *note*
PRAIRIES, character and origin of, 390, *note*
PRECIPITATION, absorption of, by earth, 21, 215, *note*
  in the United States, 217, *note*
  in Lombardy, 456, *note*
  extraordinary, at Genoa in October, 1872, 279, *note*
  how much lost by evaporation, 472
  plans for economizing, 487

QUADRUPEDS, domestic, origin and transfer of, 86, 87
  domestic, number of, in the United States, 88
  wild, number of, in the United States, 88
  extirpation of, 92–96
QUARRIES, extent of, 403, *note*
QUEBEC, high tides at, 360, *note*
  lumber trade of, 360, *note*

RABBIT, injurious in Australia, 89, *note*
RAILWAYS, scientific uses of, 53, *note*
  consumption of timber by, 355
RAIN, summer, how far lost by evaporation, 216
RAIN WATER, its absorption and infiltration, 474
  economizing its precipitation, 487
RAVENNA, cathedral of, 62, *note*
RED SEA, richness in organic life, 98
  diversion of the Nile to, its effect, 621
REPTILES, utility and destruction of, 125
RESERVOIRS, natural subterranean, 474
  as remedies against inundations, 492
  natural, 494
REVENTLOV's organization of dune economy in Denmark, 595
REVOLUTION, French, influence of, on woods, 354
RHINE, discharge of, in flood, 297, *note*
  ordinary discharge of, 519, *note*
  sediment of, 543
  diversion of, 624
RHONE, discharge of, 519, *note*
RICE, cultivation of, unhealthy, 467
  climatic limits of, 468, *note*
  introduced into Europe by Moors, 468, *note*
RITTER's opinion on Egypt erroneous, 455, *note*
RIVERS, fertilizing slime of, 244, *note*
  origin of, 268, 505, *note*
  transporting power of, 274
  sediment of, its extent, 275
  injury to their banks by lumbermen, 364
  underground and submarine, 472, *note*
  intercommunication of, 497, *note*
  diversion of water from, effects of, 498, *note*
  effect of obstructions in, 505, *note*
  confluence of, effect on the current below, 505, *note*
  great, proposed diversion of, 624
RIVER BEDS, natural change of, 498
  artificial change of, 498
          in Egypt, 498
          in Italy, 499
          in Switzerland, 500
RIVER DEPOSITS, 504
  of the Po, 279, 506, *note*
  of the Nile, 525
  of the Tuscan rivers, 525
RIVER EMBANKMENTS, 501
  their effects, 502
RIVER MOUTHS, obstructions of, 522
  accelerated by man's influence, 523
  effect of tidal movements, 524
ROBIN, the American, voracity of, 121, *note*
ROCK, generally permeable by water, 285, *note*
  cuttings in England, 403, *note*
  soil beneath, 628
  covering with earth, 629
ROMAN CAMPAGNA, insalubrity of, 447, *note*
ROMAN EMPIRE, physical advantages of its territory, 1
  physical decay of its territory, 3, 5
  causes of this decay, 5, 7
ROME, commerce of, passive, 65, *note*
  objects of, 65, *note*
  insalubrity of, 158, *note*
ROMANS and Greeks, great material works of, 426
  contempt for artisans and engineers, 426
ROOTS of trees, influence of, on drainage, 242
ROZET's plan for diminishing inundations, 512
RUBBISH HEAPS in Egypt, 641
  of Monte Testaccio, 641
RUDE TRIBES, continuity of arts among, 17
  commerce of, 18
  relations to organic life and nature, 38, *note*
RUSSIA, diminution of forests in, 324
  diminution of forests in, effect of, on rivers and lakes, 325, *note*
  attempts to reclaim the sands, 608, *note*

SACRAMENTO CITY, effect of river dike at, 508, *note*

SALT, waste of, 37, *note*
  possibility of washing out from land, 436, *note*
SAND, chapter on, 545-605
  quartz grains most abundant in, 545
  of desert, generally derived from upheaval of sea-bottom, 546
  how formed at present, 546
  generally of ancient formation, 547
  of coast of France and Denmark, 547, *note;* 551, *note*
  how carried to the sea, 548
  of Sinaitic Peninsula, 548, *note*
  of Northern Africa, 550
  of Egypt, 552
  drifting, movement of, 553, *note*
  polishing action of, 553, *note*
  storms, exaggerations respecting, 554
  dunes and sand plains, 558
  plains, inland, 603
  of Belgium, 607
  of eastern Europe, 608
SANDAL-WOOD, extirpation of, in Juan Fernandez, 383, *note*
SAND-BANKS, structure of, 565
  marine, 565
SAND-SPRINGS, 605
SANDSTONE of Arabia Petræa, 546, *note*
  originating in dunes, 574
SAP of maple and birch, 184
SAROS, projected canal of, 615
SAVAGE TRIBES, arts of, 17
  commerce of, 18
  interfere little with nature, 38, *note*
  first domesticate wild animals, 38, *note*
  sympathy of, with animals, 38, *note*
SAWMILLS, whether action of their machinery more rapid by night, 366, *note*
SCHELK, the extirpation of, 98
SCHLEIDEN, on exhalation of aqueous vapor by trees, 188
SCHLESWIG-HOLSTEIN, encroachments of sea on, 586
SEA, exclusion of, by dikes in Lincolnshire, 403
  encroachments of, 583 *et seqq.*
    the Liimfjord, 583
    in Schleswig-Holstein, Holland, and France, 586
SEA-COW, Steller's extirpation of, 105
SEAL found far from the sea, 99
  voracity of, 106
SEDIMENT, river, geological importance of, 399, *note*
SEEDS, transportation of, by birds, 111
  vitality of, 293-296
SEINE, ancient uniformity of volume of, 236, *note*
  ordinary and flood discharge of, 236, *note*
  affluents of, 471, *note*
  supply and discharge of, 472, *note*
SERPENTS, multiplication of, in France, 126, *note*
  human lives destroyed by, in India, 126, *note*
SHARK, fishery of, 105, *note*
SHELTER afforded by forests, 156-159
SHIP-BUILDING of the Middle Ages, 321
SIBERIA, ice ravines in, 174
SICILY, sulphur mines of, 79, *note*
  olive-oil crop of, 339, *note*
SILKWORM, new, introduction into America, 136
SILPHIUM, extirpation of, 77, *note*
SINAI, MOUNT, rain torrents at, 477, *note*
  production of sand in peninsula of, 548
  garden of monastery at, 629
SIEMONI, on action of woods on springs, 225
SLIDES, mountain, 284-289
SLIME, river, fertilizing qualities of, 244, *note*
SMITH, Baird, on irrigation, 460, *note;* 463, *note*
SNAKES destructive to insects, 125
  tenacity of species, 126
  number of, 126, *note*
SNOW in the woods in winter, 208, 215, 216
  and ice, condensation of moisture by, 210
  crust of, how formed, 210, *note*
  thaws the ground beneath it, 210, 231
  plants grow under, 212, *note*
  temperature of, 212, *note*
  quantity of, in woods, 213
  and ice, accumulation of, in mountains, 215, *note*
SOIL, secular desiccation of, 20, *note*
  new, favorable to growth, 20, *note*
  amount of thermoscopic action on various, 167
  mechanical effect of shaking, in Netherlands, 415, *note*
  effect of frost on, in United States, 416, *note*
SOLAR HEAT, utilization of, 46, *note*
  action of, on stone, 551, *note*
SOUND, transmissibility of, 160, *note*
SPAIN, neglect of forest culture in, 306
SPRINGS, artificial, 482
SQUIRREL, destructiveness of, in forests, 85, *note*
STARLING, habits of, in Piedmont, 125, *note*
ST. HELENA, flora of, 66
  destruction of its forests, 383, *note*
STONE implements, modern use of, 17
STORK, anecdote of a, 114, *note*
  geographical range of, 112, *note*
SUBTERRANEAN WATERS, their origin, 469
  of the Karst, 470, *note*
  of Greece, 470, *note*

sources of supply, 472
reservoirs and currents of, 474
diffusion of, in soil, 474
SUEZ CANAL, effect of, on the Mediterranean and Red Sea, 97
excavations for, 403, *note*
danger from sand drifts, 554
SUGAR-CANE, introduction of, into Europe and America, 75, *note*
SUGAR-MAPLE TREE, produce of, 184
SUNFLOWER, effect of plantation of, 157
SWALLOW, popular superstition respecting, 533
SWITZERLAND, ancient lacustrine habitations, 16, 77
SYLT Island, sand dunes of, 563
encroachment of the sea upon, 563
SYLVICULTURE, best manuals of practice of, 368, *note*
its methods, 372
the *taillis* treatment, 374
the *futaie* treatment, 374
beneficial effects of irrigation in, 376
removal of leaves in, 379
exclusion of animals, 382, *note*

TAGUATAGA LAKE, Chili, draining of, 432, *note*
TEMPERATURE, how affected by elevation, 52, *note*
TEREDO, the general diffusion of, 137
TERMITE, or white ant, ravages of, 137
THRESHING MACHINES, saving by, 86, *note*
TIBER, subterranean reservoirs in valley of, 474
TICK, wood, disappearance of, in North-eastern States, 184, *note*
TIMBER, increased demand for, 355
of natural growth, inferiority of, 369
TORRENTS, destructive action of, 245
in South-eastern France, 246–256
deposits of, in beds of rivers, 237, *note*
in the Himalayas, 263, *note*
excavations by, 263
action of, in elevating the bed of streams, 264
of the Nautzenthal, 267
of the Litznerthal, 267
whether origin of rivers, 268
extinguished, 269
crushing force of, 271–274
danger of, in the United States, 328
TOYS, children's, consumption of wood for, 358, *note*
TRANSPORTATION, facilities of, effect of, on commerce, 65, *note*
TREES, forest, succession of species in, 18, *note*
how far injured by small animals, 83, *note*
improvement of, by cultivation, 59, *note*
evergreen, power of resisting frost, 175, *note*
how far they interrupt precipitation, 181, *note*
absorption of vapor by, 186
absorption of moisture from the earth by, 186
exhalation of moisture by, 189–191
drainage of soil by roots of, 203
evergreen, alleged desiccatory action of, 207, 208, *note*
names of, vaguely applied, 308, *note*
rapid growth of, in Italy, 318
forest, American, 330–334
their dimensions, 331
change in relative proportion of height and diameter, 331
comparative longevity of, 333, *note*
American compared with European, 334–342
destruction of evergreen, for decorative purposes, 357, *note*
hill plantations of, 379
powers of resisting action of fire, 384, *note*
planting of, on sea-coast, 389
TRIESTE, proposed supply of water to, 470, *note*
TROUT, the American, 99, 108
TUNNEL of Mt. Cenis, statistics of, 403, *note*; 406, *note*
of Lake Copais, 427
TURTLES' eggs, destruction of, 108, *note*
TUSCANY, rivers of, their deposits, 525
physical restoration in, 527
improvements in the Maremma, 528
Val di Chiana, 532
TYROLESE rivers, elevation of their beds, 265, *note*

UNDULATIONS of water, 550
UNITED STATES, foreign plants grown in, 68
weight of annual harvest in, 73
number of quadrupeds in, 87
birds in, 118
forests of, 327
instability of life in, 396
URUS or auerochs, domesticated by man, 93
extirpation of, 95

VAL DI CHIANA, improvements in, 532 *et seqq.*
VAPOR prevents escape of heat by radiation, 172
condensation of, by snow and ice, 209
and cloud attracted by mountains, 216, *note*
VEGETABLE LIFE, how affected by animals, 83
VEGETABLES, cultivated European, not indigenous, 2
acclimation of, 16
geographical importance of, 42, 44
meteorological action of, 62, *note*

  domestic origin of, 59, 60, *note*
  modification of, 60, *note*
  improvement of, by cultivation, 59, *note*
  early garden, sent from Algeria and Naples to Northern Europe, 65, *note*
  transfer of, 64, *note*
  foreign, how introduced, 65–67
  power of accommodation, 70–73
  American, grown in Europe, 76
  extirpation of, 76
  indigenous, dying out in America, 79
Vesuvius crater, wooded inside, 150
Vine, in what countries indigenous, 71, *note*
  dimensions of, 71, *note*
  European, introduction of, into America, 71
  injury to, by parasites not economically injurious to vine-grower, 79, *note*
Viper, multiplication of, in France, 126, *note*
Volcanoes, eruptive matter of, not infertile, 150
  resistance to action of, 637
Volga, proposed diversion of, 621

Walcheren, formation of the island of, 411
Wallenstadt, lake of, diversion of Rhine into, 624
Walnut tree, oil yielded by, 337, *note*
  consumption of, for gunstocks, 356, *note*
Ward's cases for plants, 188
War, instrumentalities of, applied to social and civil purposes, 406, *note*
Waste, modern mode of economizing, 35, *note*
Water, chapter on, 398 *et seqq.*
  land won from, 398
  subterranean, 469 *et seqq.*
  infiltration of, 463, *note*
  fresh on sea-beaches, 477, *note*
  not found at great depths in boring, 480, *note*
Weather, action of man upon, 634
Weeds, common to Old and New World, 72
  extirpation of, in China, 78
Wells. See *Artesian Wells*.
  tubular, 476, *note*
Whale, food of, 103
  destruction of, 104
Whale-fishery, when first practised, 102, *note*
  American, 103
Wheat, its asserted origin, 59
  how introduced into America, 68, *note*
Wild animals, numbers of, 82
Wild organic life, superior hardiness of, 73
Winkler, work on dunes, 546, *note*
Wolf, increase of the, 91
  prevalence of, in forests of France, 313, *note*
Woods, native American, permanent character of, 26

  generally, Chap. III., 148
  general meteorological action of, 152
  electrical influence of, 153
  whether preventive of hail, 153
  chemical influence of, 155
  of Australia and New Zealand, 155, *note*
  as protection against malaria, 156
  in Southern Hemisphere evergreen, 159, *note*
  as a shelter of ground to the leeward, 159
  as inorganic matter, influence of, on temperature, 167–171
  specific temperature of, 172–177
  evaporation from earth of, 181, *note*
  exhalation of vapor by, 176
  intercepting rain by foliage of, 180
  organic action of, 182
  balance of conflicting influences of, 191
  influence on precipitation, 193–197
  on humidity of soil, 203
  in winter, 208–215
  influence of, on flow of springs, 218
  on inundations and torrents, 231–236
  mechanical resistance of, to flow of water, 235
  effect of, in disintegration of soil, 241
  influence of, on drainage, 242
  protection against avalanches, 290
  minor uses of, 292
  utility of, in preserving small plants, 293
  protection against locusts, 299
  summary of influences of, 299
  general consequences of destruction of, 300
  proper proportion of, 302
  in different countries, 304 *et seqq.*
  in Great Britain, 307–312
  in France, 312–318
  in Scotland and Egypt, 311
  Southern France, 313
  legislation on, in France, 316
  in Italy, 318–323
  in Russia, 324
  in American States, 326
  do not furnish food for man, 343
  first removal of, 344
  burning over for agricultural purposes, 345
  principal causes for destruction of, 346
  affected by game laws and French revolution, 349–352
  restoration of, 366
  management of, 367
  cultivation of, 371–379
  injured by removal of leaves from ground, 381
  destructive action of cattle on, 382, *note*
  fires in, 384–386

plantation of, in United States, 388
legislation on, 386–390
rules for planting in, 392
economical results of, 393 *et seqq.*
profits of, 394
increased demand for, 355
consumption of, as fuel, 357, *note*; 357
replaced by iron in the arts, 357
means of increasing its durability, 358, *note*
quality of, how affected by rapid growth, 370, *note*
facilities for working, 370, *note*

WOODPECKER, red-headed, disappearance of, from Eastern States, 140
destruction of insects by, 136

WORMS, earth, useful to agriculturists, 130

YEW TREE, geographical range of, 78

ZUIDERZEE, proposed draining of, 422
geographical results, 425